Naval Research Laboratory
Washington, DC 20375-5000

NRL Memorandum Report 6447

Full Scale Smoke Curtain Tests — 5 - 10 October 1986

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June 7, 1989

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b DECLASSIFICATION / DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) NRL Memorandum Report 6447	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Naval Research Laboratory 6b OFFICE SYMBOL (If applicable) Code 6183	7a NAME OF MONITORING ORGANIZATION
6c ADDRESS (City, State, and ZIP Code) Washington, DC 20375-5000	7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING / SPONSORING ORGANIZATION Naval Sea Systems Command 8b OFFICE SYMBOL (If applicable) Code 05R23	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code) Washington, DC 20362-5101	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: 63514N PROJECT NO: TASK NO: WORK UNIT ACCESSION NO:
11 TITLE (Include Security Classification) Full Scale Smoke Curtain Tests - 5 - 10 October 1986	
12 PERSONAL AUTHOR(S) (See page ii)	
13a TYPE OF REPORT Final 13b TIME COVERED FROM 1985 TO 1986	14 DATE OF REPORT (Year, Month, Day) 1989 June 7 15 PAGE COUNT 280
16 SUPPLEMENTARY NOTATION (See page ii)	

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Fire hazards, Scaling, IR camera Suppression, Fire spread, Smoke Fire fighting,

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Findings from these full-scale integrated smoke curtain tests show a high potential in the use of smoke curtains for containing and limiting the spread of smoke during and after a shipboard fire. They also showed a marked tendency to inhibit the growth of fire when deployed in key locations by curtailing the air supply to the fire. They were accepted most heartily by the crew of the USS SPRUANCE, DDG 963, as an aid to fire fighting. These tests also showed two areas of improvement needed for the application of the curtains: the method of attachment, and a need for guidelines on when and where to deploy them.

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL Frederick W. Williams	22b TELEPHONE (Include Area Code) (202) 767-2476 22c OFFICE SYMBOL Code 6183

DD Form 1473, JUN 86 *Previous editions are obsolete* SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603

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16. SUPPLEMENTARY NOTATION

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FULL SCALE SMOKE CURTAIN TESTS — 5 - 10 OCTOBER 1986

INTRODUCTION

Where there is fire there is smoke! In fact, in the majority of fires, the smoke and toxic gases spread much faster and further than the fire. The smoke hampers escape, rescue and fire fighting. This is especially true in confined areas such as aboard ships. There are vertical zones, known as water-tight boundaries, built into ships below the water line which inhibit the spread of smoke. These boundaries lose meaning and in many cases are non-existent in the superstructure where many of the vital spaces of a ship are located.

There are several physical processes which contribute to the spread of smoke. Buoyant forces, caused by differences in gas densities, drive smoke upward and draw air into the fire. Air flow patterns are set up through natural or enemy induced openings via this air pump phenomena. In addition, an over pressure is created when a fire is confined below decks which can drive the smoke in every direction, even downward.

In some instances it is difficult to secure all fire relevant mechanical exhaust and supply ventilation which contribute to smoke spread. It becomes evident then that the role of smoke curtains could be two fold, i.e., stop the spread of smoke and toxic gas and limit the supply of fresh air to the fire. This report deals with both applications of smoke curtains.

In a cooperative program with the U. S. Coast Guard's Fire and Safety Test Detachment, Mobile, AL, the David Taylor Research Center (DTRC), and the Naval Research Laboratory (NRL), the smoke curtain tests were conducted during 5-10 October 1986 aboard the U. S. Coast Guard's Fire Test Ship, A. E. WATTS (1). Navy fire fighters, smoke curtains and desmoking teams were furnished by the USS SPRUANCE, DDG 963 under the direction of the Damage Control Assistant LT(JG) Michael Brown, USN. The U.S. Coast Guard test director was LCDR Harry Schultz, USCG and the Navy's test director was Dr. Frederick W. Williams. Mr. Terry Toomey of Hughes Associates acted as technical advisor to the fire fighters and Mr. Richard Carey of DTRC was technical advisor for the smoke curtains.

Manuscript approved February 17, 1989.

The primary objectives of the tests were to demonstrate the usefulness of portable smoke curtains in limiting the spread of smoke in a shipboard environment and to test several different designs of curtains and materials. Since the curtains were designed to be portable, the method of their attachment, as well as the timing and location of their deployment also had to be evaluated. As a side issue, the ability to desmoke after and during fire fighting was assessed.

The ultimate testing of the curtains under anything short of a realistic shipboard fire with actual fire fighting would have yielded unauthentic and unsatisfactory data. In addition, with the involvement of fire fighters as an integral part of the picture, it seemed prudent to use a fire fighting crew who would ultimately use the smoke curtains in the fleet. Therefore, it was decided to use the volunteer services of the crew of the USS SPRUANCE, DDG 963. This ship was undergoing overhaul at Ingalls Ship Building and Repair, Pascagoula, MS. The SPRUANCE furnished the manpower (more than 80% of the crew over a 5-day period) and the damage control equipment from their repair lockers. The willingness of their Commanding Officer, CDR G. Gottschalk, and the enthusiastic support of the Damage Control Assistant, LT(JG) Michael Brown were instrumental in making these resources available.

EXPERIMENTAL CONFIGURATION

The after superstructure (main deck, 01 and 02 level) of the A. E. WATTS, a T2 tanker, was used as the test area. Schematics of the test areas are presented in Figs. 1-3. Since the fires were confined to specific compartments, wooden bulkheads were created to limit the spread of smoke. The placement of the infrared cameras for seeing through smoke is shown in Figs. 1-3 and is designated as NFTI (Navy Firefighting Thermal Imager). The video camera locations are also shown in Figs. 1-3. Still photos were taken before, during, and after each test. The two fire rooms employed in these tests are shown in Fig. 2, designated as #1 and #2. The archways, shown in Figs. 2 and 3, were of wood construction with a metal lip and are similar to those found in water-tight bulkheads with doors and on the gallery deck in an aircraft carrier.

Smoke curtains designed for hatches, passageways and doorways were evaluated, as are shown in Figs. 4-7. The blanket curtain (Fig. 7) is designed for hatches and ladderways while the other designs (Figs. 4-6) are for joiner doors, archways, and water-tight doors. Rubber tires were used as fuel along with a modest amount of electrical cables to make the smoke more acrid. Liquid fuel was placed in the rims and ignited manually. The burning rate of the fuel was monitored with a load cell. Other equipment integrated into the tests included the Navy's new Nomex engineer's coverall, rain gear, the Navy Infrared Thermal Imager and a proposed fire fighting suit. Portable Red Devil

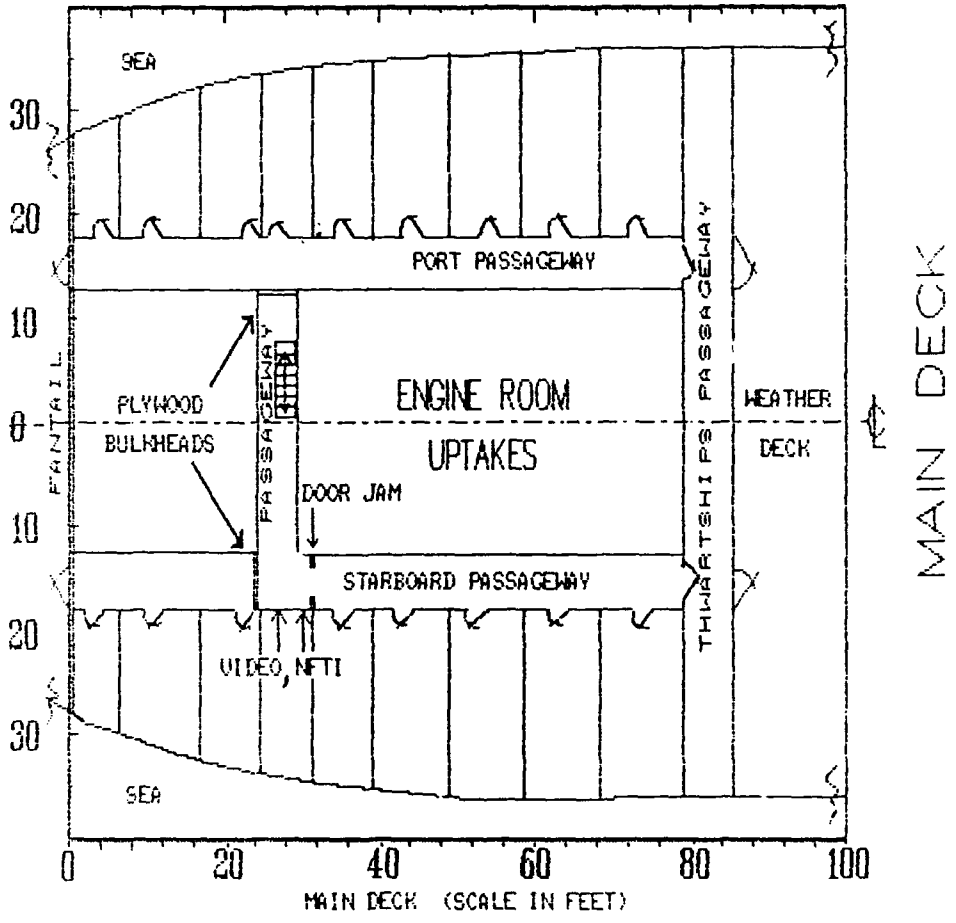


Figure 1

After Section of Albert E. Watts, Main Deck

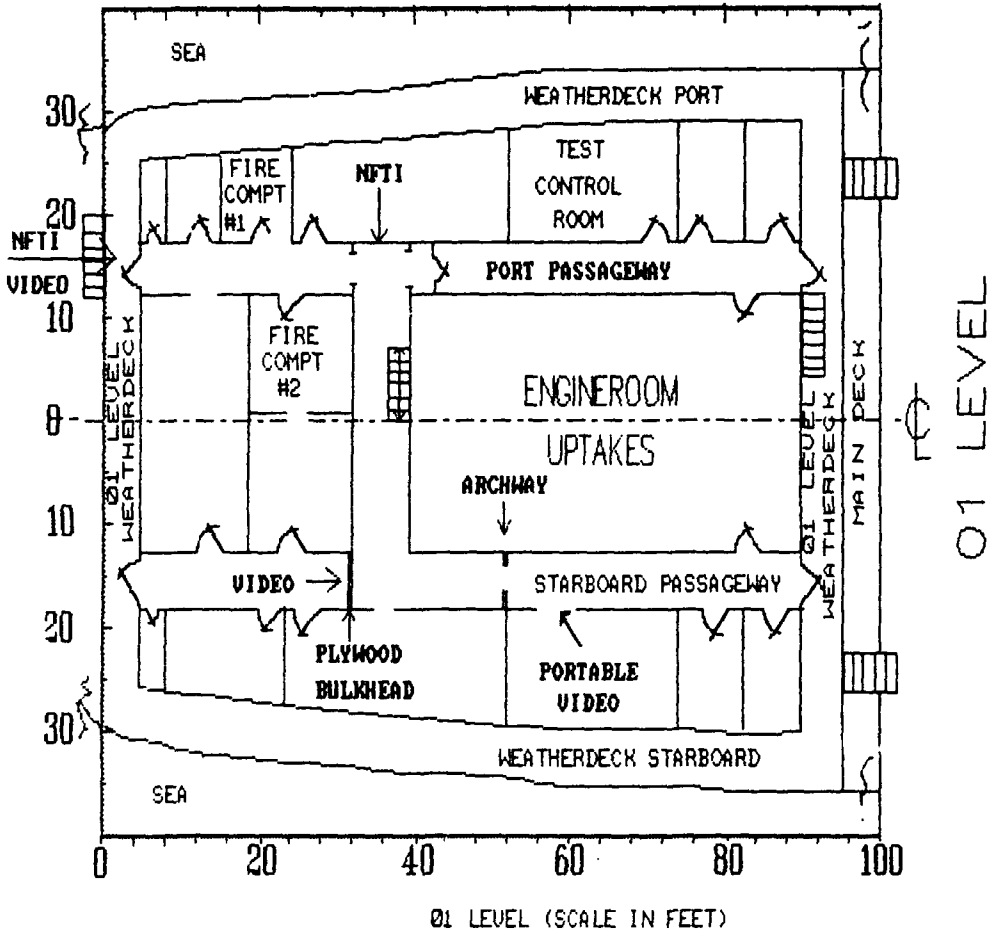


Figure 2

After Section of Albert E. Watts, 01 level

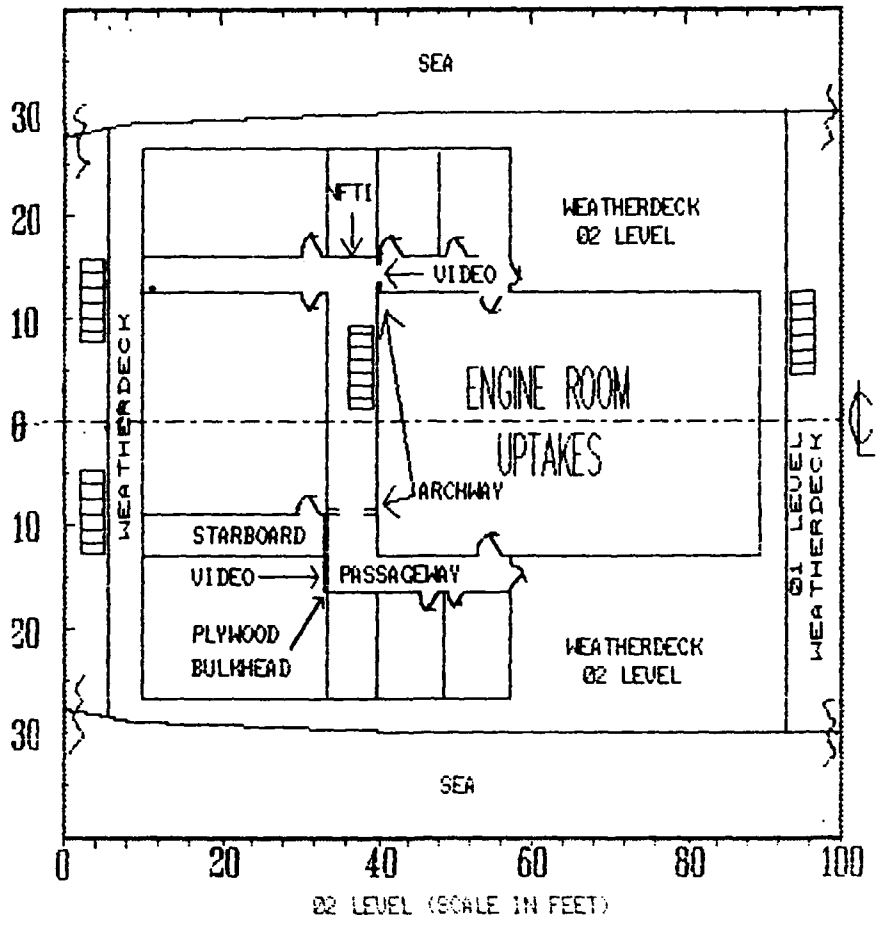


Figure 3

After Section of Albert E. Watts, 02 level

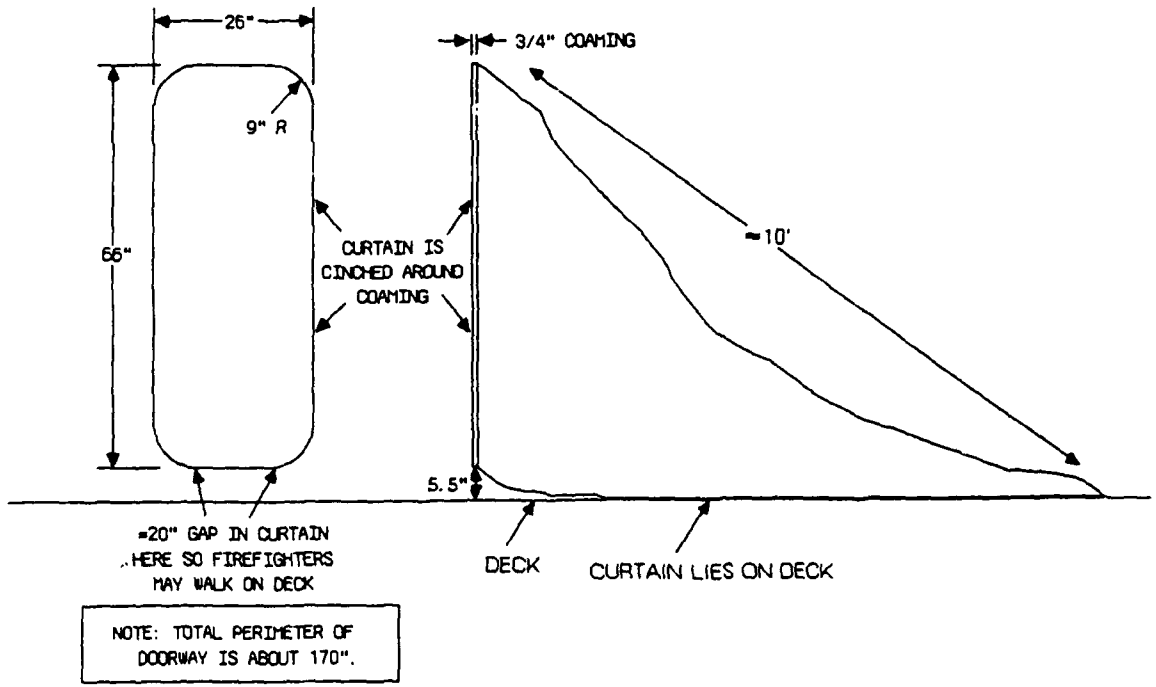


Figure 4a

Smoke Curtain Elephant Trunk/Blanket Design

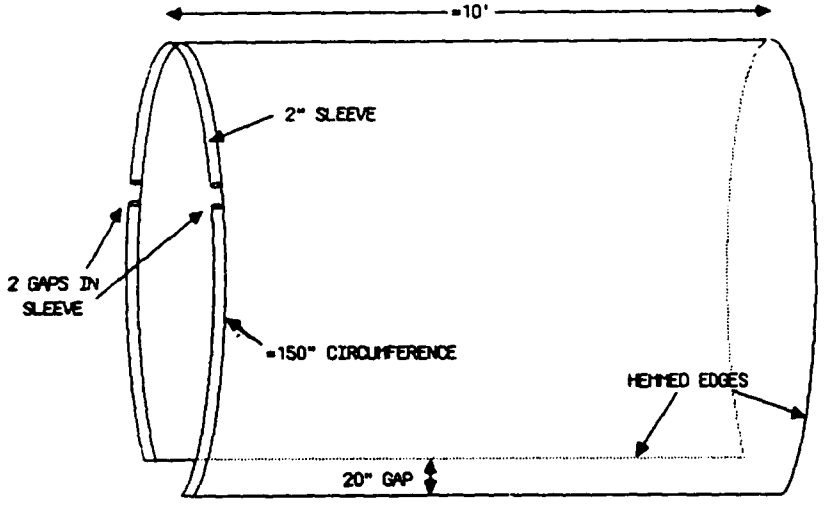


Figure 4b

Smoke Curtain Elephant Trunk/Blanket Design

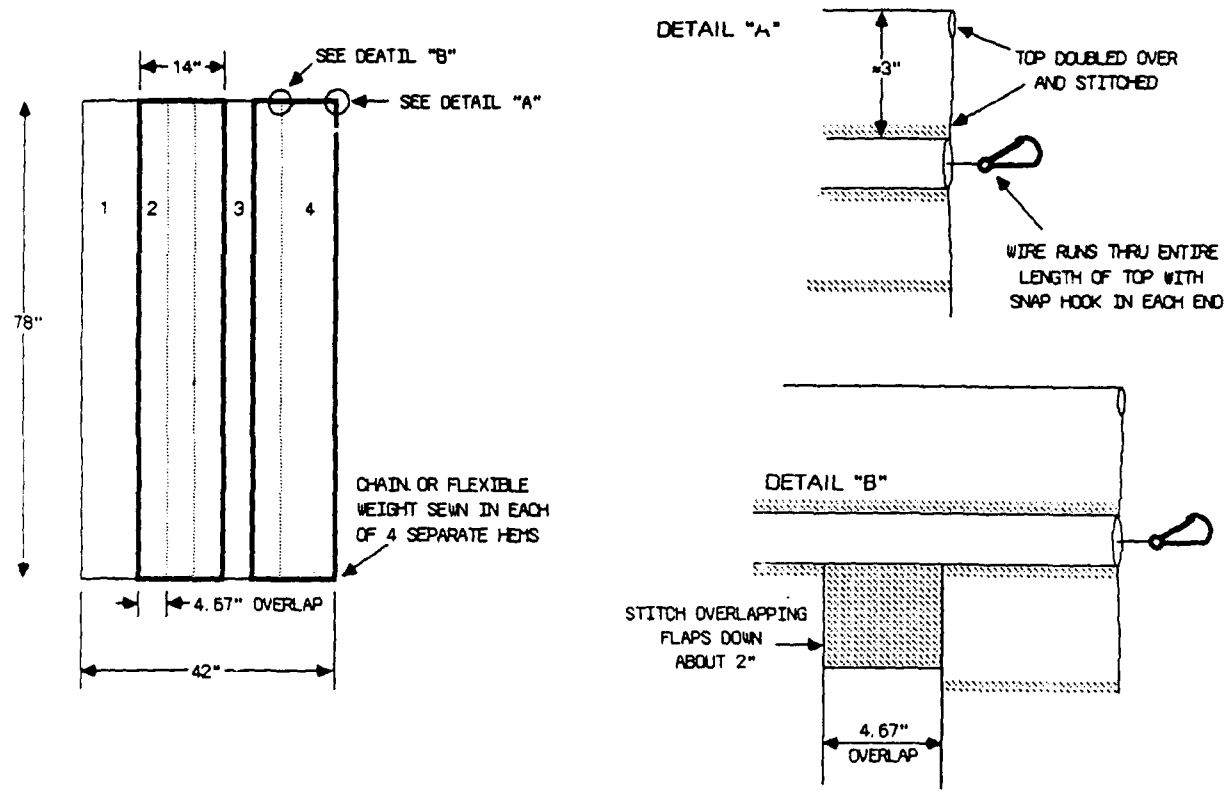


Figure 5

Four strip Smoke Curtain Design

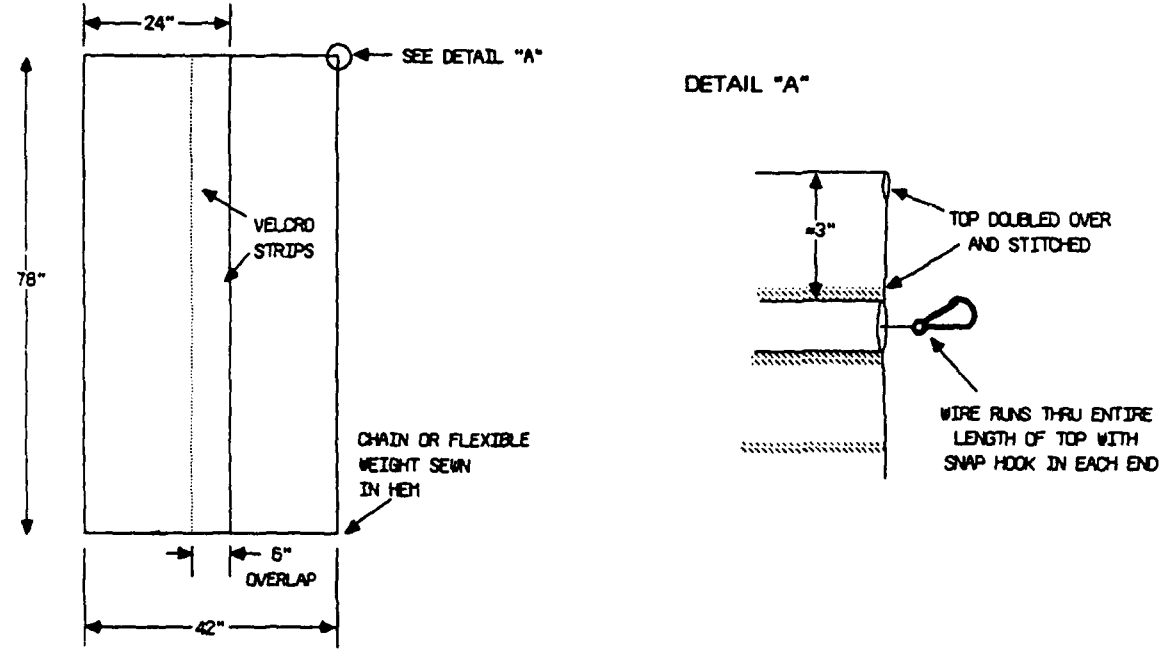


Figure 6

Two strip Smoke Curtain Design

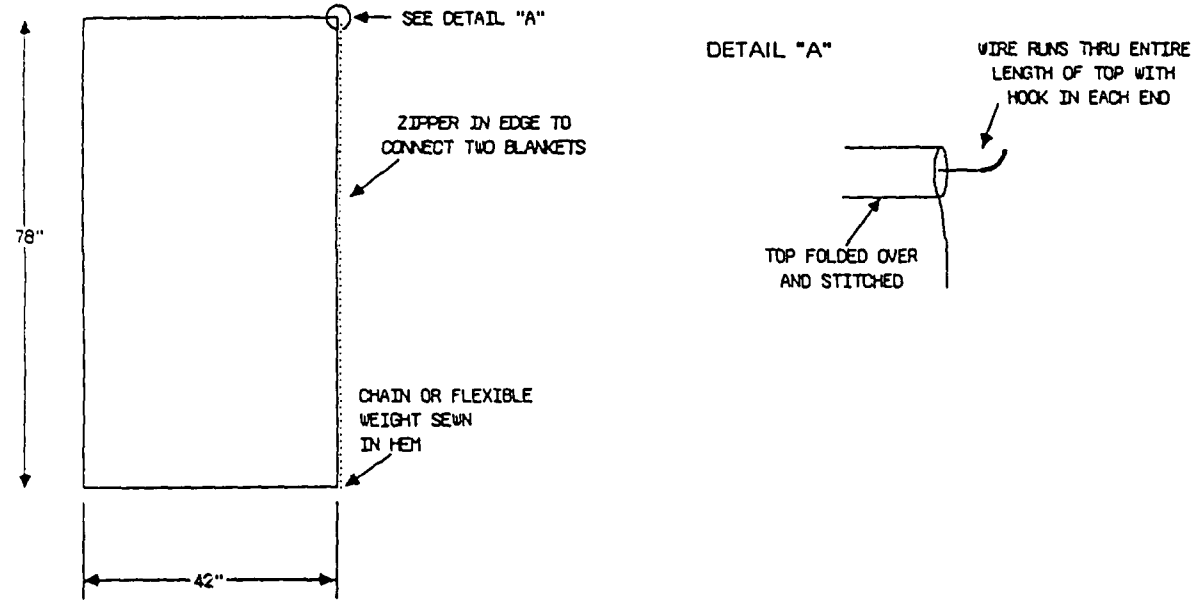


Figure 7

Smoke Curtain Blanket Design

blowers were used for desmoking as part of the evaluations. Table I summarizes the fire loads and types, number of smoke curtains used, involvement of fire fighting, type of clothing, infrared cameras used and desmoking activity.

Temperatures throughout the test area were continuously monitored with chromel-alumel thermocouples (TC) recorded by a Hewlett Packard 9000 series computer. The locations of the thermocouples are presented in Figs. 8-10. Vertical strings of TC's were used to obtain temperature profiles. The couples were placed 0.6, 1.2, 1.8, and 2.1 m (24, 48, 72 and 84 in) from the deck. The two thermocouples over the fire pan were 0.6 and 0.9 m (24 and 36 in) above the pan. Both rooms had the same designation for these two TC's, therefore only the room containing the fire was monitored during a test. Thermocouples 94, 90 and 98 were single couples located 1.2 m (48 in) above the main deck.

Gas analysis consisted of continuous monitoring of oxygen, carbon monoxide and carbon dioxide using Beckman Gas Analyzers at selected locations shown in Figs. 11-13. In most locations, gas was sampled at both 0.9 m (3 ft) and 2.1 m (7 ft). Otherwise, samples were taken at only the 1.2 m (4 ft) level.

TEST PROCEDURE

The tests were designed to simulate a shipboard fire which generates large amounts of smoke. The fires were set in one of the two compartments on the 01 level, designated as compartments #1 and #2 in Fig. 2. In order to bracket the generic fire, two calibration fires were run. One was a class B fire consisting of 18.9 l (5 gal) of diesel fuel in a 1.2 m x 1.2 m (4 x 4 ft) area. The other was an ASTM standard class A 113 Kg (250 lb) wood crib fire. The actual fires for the smoke curtain tests were burning rubber tires which produced large volumes of smoke.

Prior to actual ignition of the fuel, all instrumentation was turned on and scanned for at least five minutes. This allowed the establishment of baseline measurements. The fuel for the initiation fire, 3.8 l (1 gal) of diesel fuel was added to the tires three minutes into the data collection phase. The video clocks were initiated at ignition. The data collection test time zero was also at this point in time. The smoke curtain/fire fighting efforts commenced at the discretion of the test director and the commencement times are summarized in Table II. Seven fire fighting tests were conducted with six employing smoke curtains.

Specifically, the test condition for each fire was as follows:

Table I - SUMMARY OF SMOKE CURTAIN TEST

Test No.	Date	Fire Type	# of Curtains Used	Fire fighting	Clothing	IR Used	De-smoking	Comments
W-35	10/5/86	Diesel Fuel	None	None	--	--	Natural	Main deck Starboard Access open (one door)
W-36	10/10/86	Wood Crib	One (fixed)	None	--	--	Natural	"
W-37	10/7/86	Tires (5)	None	None	--	--	Natural	"
W-38	10/7/86	Tires (5)	None	Conventional	Conventional	None	De-smoke after fire out	Attack at 02 level, Main deck Starboard Access open (one door)
W-39	10/8/86	Tires (9) & Electric cables	One (out of 5) (Not installed functionally)	None	Conventional	None	None	Attack at 01 level, Main deck Starboard Access open (one door)
W-40	10/8/86	Tires (9) & Electric cables	Pre-install fire curtains	Conventional	Rain gear	Yes	Yes	Attack at 01 level, Main deck Starboard Access open
W-41	10/9/86	Tires (8) & Electric cables	Deploy one, 01 Arch, Pre-installed 01-Main hatch, 02 Archway Starboard	Conventional	Rain gear	Yes	Yes	Successful installation
W-42	10/9/86	Tires (8) & Electric cables	Deploy one curtain- 01 Archway	Conventional	Turnout & rain gear	Yes	Yes	Successful installation
W-43	10/10/86	Tires (9) & Electric cables	Deploy two curtains- 01 Archway, Blanket between 01 & 02	Conventional	Rain gear & turnout	Yes	Yes	Successful installation
W-44	10/10/86	Tires (9) & Electric cables	Deploy three curtains- 01 Archway, 01 & 02 Hatch, 02 Archway	Conventional	Turnout & rain gear	Yes	Yes	Hose Team led by Toomey. Successful installation

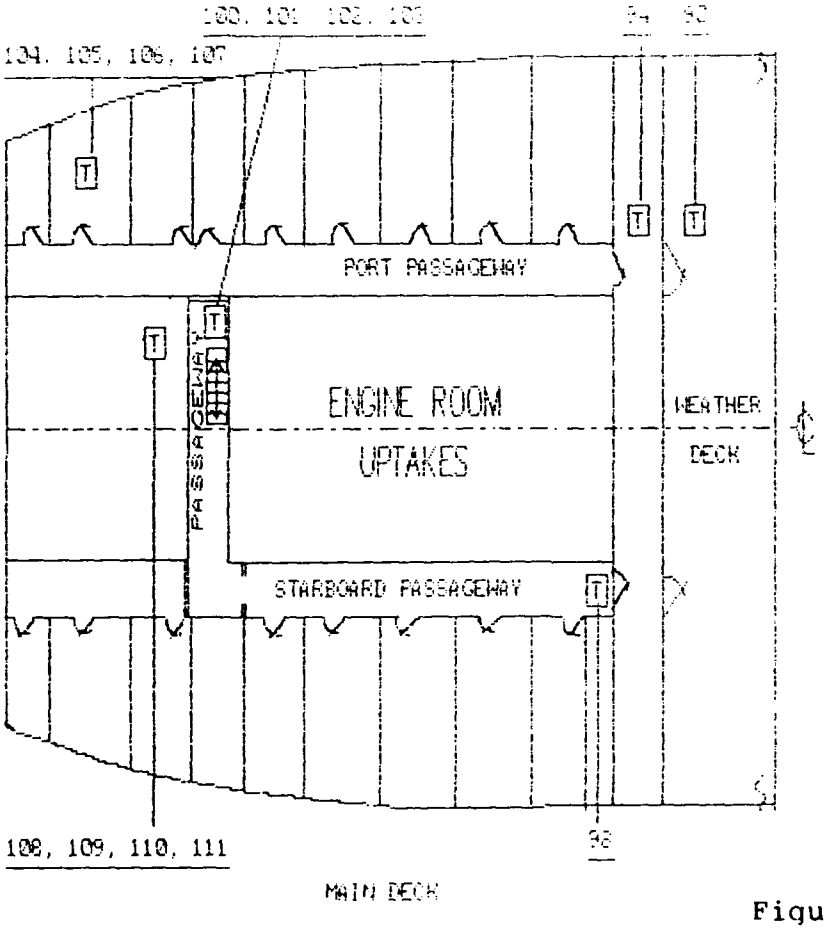


Figure 8

Main Deck Temperature Sensor locations

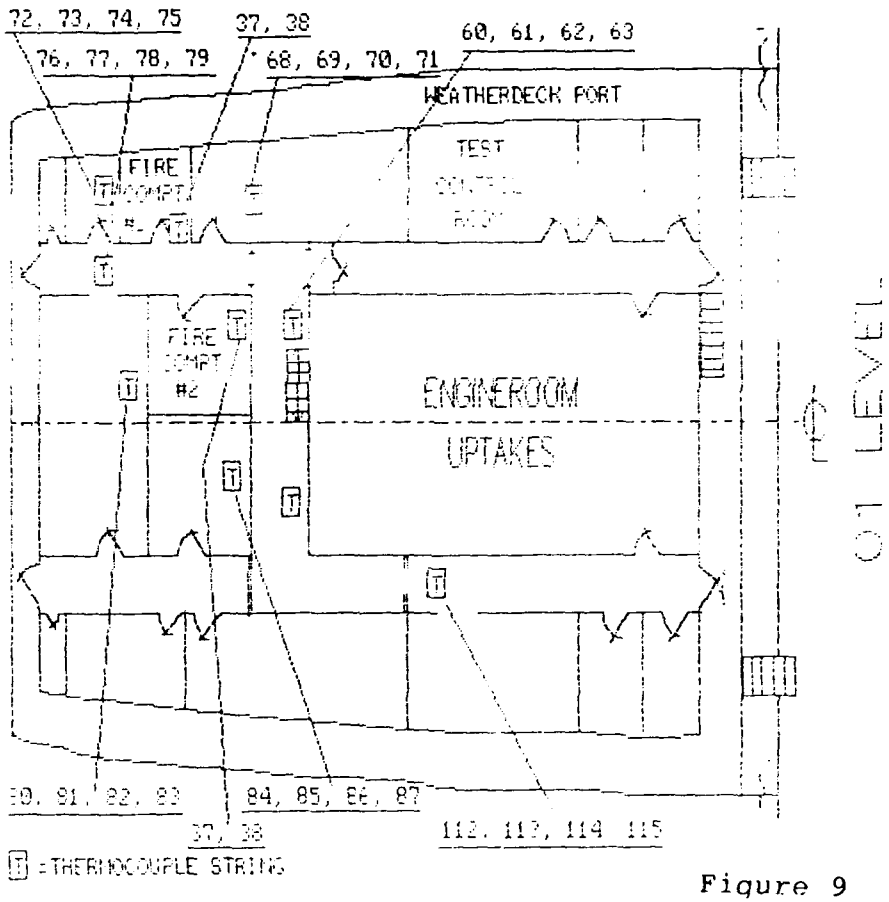


Figure 9

01 LEVEL 01 Level temperatures sensors locations

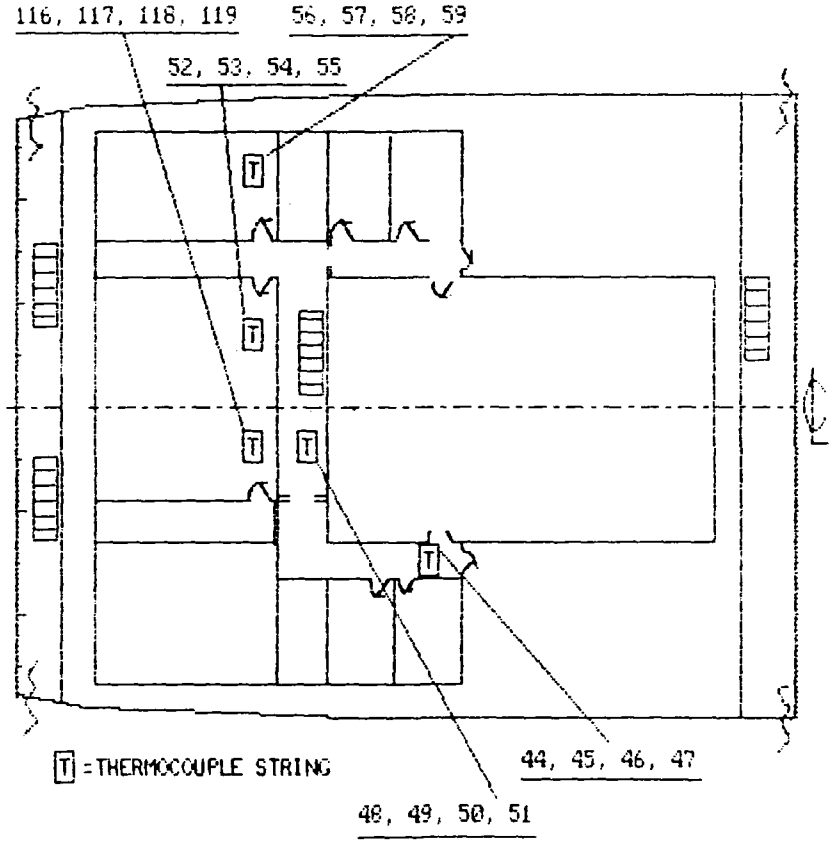


Figure 10

02 Level temperature sensors locations

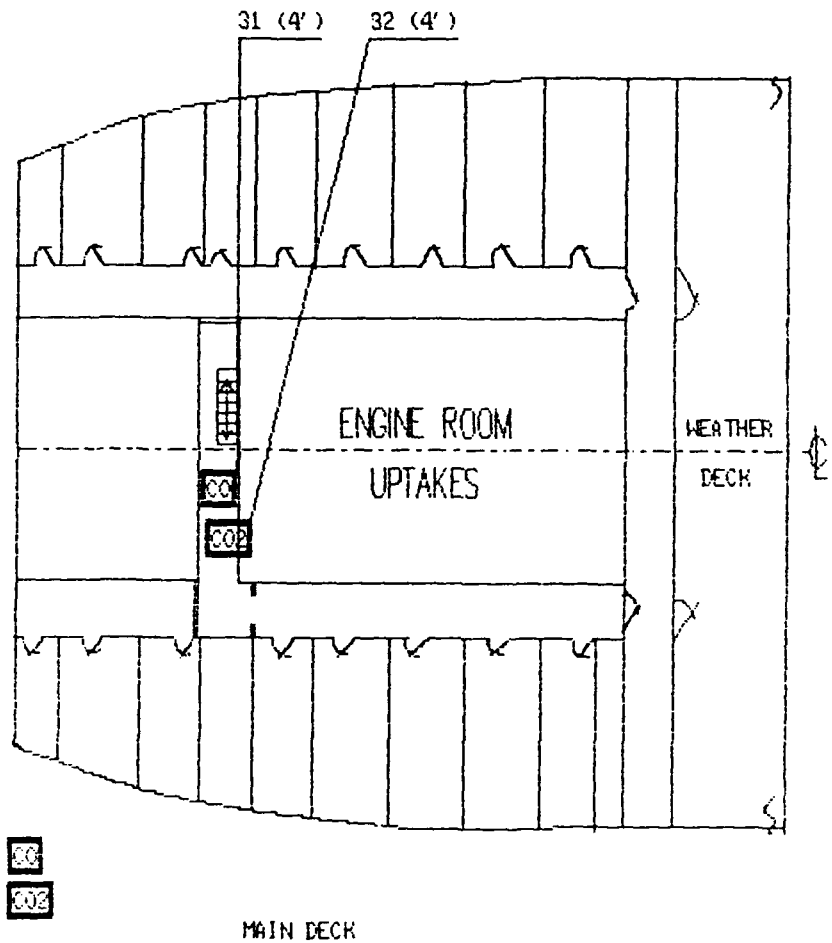


Figure 11

Main Deck Gas sampling positions

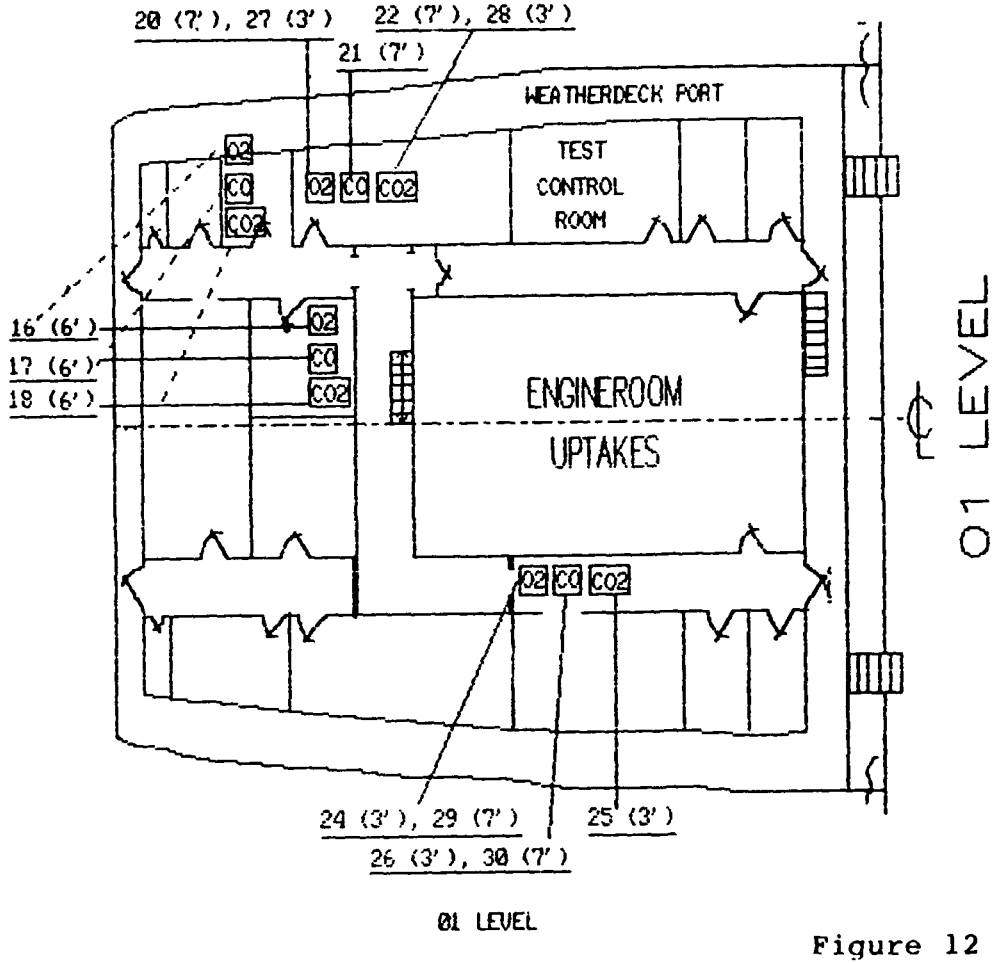


Figure 12

01 Level Gas Sampling positions

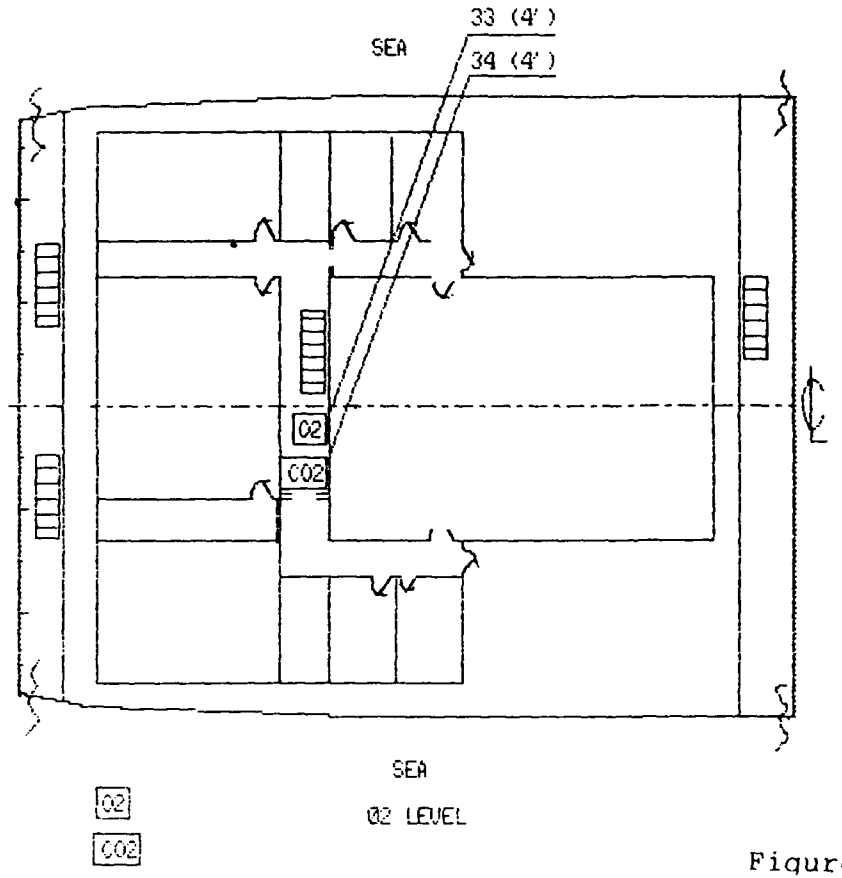


Figure 13

02 Level Gas Sampling positions

Table II - Significant Test Events

Event	Test No. Times, Absolute hr:min:sec. / Duration min:sec.						
	W-38	W-39	W-40	W-41	W-42	W-43	W-44
Fire Start	14:02:17 00:00	11:01:40 00:00	14:47:00 00:00	10:23:25 00:00	13:26:29 00:00	09:56:00 00:00	13:39:00 00:00
Investigative Team Enters Ship	14:22:45 20:28	11:11:00 09:20	15:01:56 14:56	10:34:05 10:40	13:36:51 10:22	10:05:50 9:50	13:46:34 7:34
Firefighters Enters Ship	14:34:28 32:11	11:27:30 25:50	15:08:21 21:21	10:41:55 18:30	13:48:55 22:26	10:14:40 18:40	13:50:35 11:35
Smoke Curtain Team Enters Ship, 01 Level	NA	11:12:56 11:16	Preinstalled	10:34:05 10:40	13:45:54 19:25	10:09:00 13:00	13:38:06 9:06
Smoke Curtain Team Enters Ship, 02 Level	NA	11:15:20 13:40	Preinstalled	NA	NA	NA	NA
Water on Fire	14:44:17 42:00	11:41:10 39:30	15:25:00 38:00	10:49:30 26:05	13:81:29 55:00	10:31:00 35:00	14:07:00 28:00
Desmoking Team Enters Ship, 01 Level	15:01:17 59:00	12:10:10 68:30	15:22:55 35:55	10:55:48 32:23	13:41:47 15:18	10:10:40 14:40	13:48:31 9:31
Desmoking Team Enters, Ship, 02 Level			15:36:30 49:30			10:23:53 27:53	

Test W-35 was a calibration test. The fire source was 75.9 l (20 gal) of diesel fuel burned in a 1.2 x 1.2 m (4 x 4 ft) area within compartment #2 (Fig. 2). All interior doors and hatches were open (Figs. 1-3) and the starboard main deck weather access was open (Fig. 1). There were no fire fighters or smoke curtains in this test.

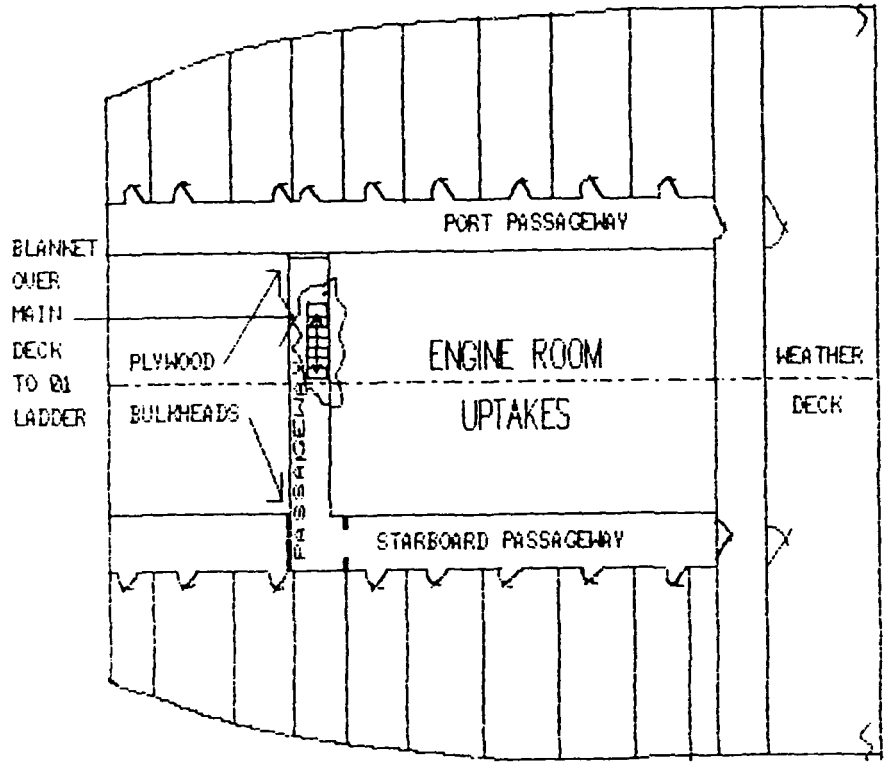
Test W-36 was a background tire fire in compartment #2 (Fig. 2) with all interior doors and hatches open (Figs. 1-3) and the starboard main deck weather access open (Fig. 1). There were no fire fighters or smoke curtains in this test.

Test W-37 was a calibration wood crib 113 kg (250 lbs) fire in compartment #2 (Fig. 2) with all interior doors and hatches open (Figs. 1-3) and the starboard main deck weather access open (Fig. 1). There were no fire fighters or smoke curtains in this test.

Test W-38 was a tire fire in compartment #2 (Fig. 2) with all interior doors and hatches open (Figs. 1-3) and the starboard main deck weather access open (Fig. 1). No smoke curtains were used but fire fighting was conducted as a base line measure. Entrance was from the 02 level (Fig. 3). Fire fighters used two 3.8 cm (1 1/2 in) hose lines, one Navy All Purpose Nozzle and one 1.2 m (4 ft) applicator. Standard procedures for establishing fire boundaries were used. This test established the baseline for the fire fighters' capability and the time required to locate and extinguish the fire using current standard outfittings and techniques. The portable IR camera, rain gear or proposed fire fighting suit was not used.

Test W-39 used nine tires and ten lengths of 3 m (10 ft) two conductor PVC electrical cable. The cable was added to make the smoke more acrid so the fire fighters were more careful about the seal on the Oxygen Breathing Apparatus (OBA). The fire was in compartment #2 (Fig. 2). All interior doors and hatches were open (Fig. 1-3) and the starboard main deck weather access was open (Fig. 1). Deployment of five smoke curtains was planned. Desmoking was also scheduled. Entrance for this test was on the 01 level starboard side (Fig. 2). The object was to establish baseline capability and time required to contain and minimize smoke migration.

Test W-40 used nine tires and fifteen 3 m (10 ft) lengths of two conductor PVC electrical cable. The fire was in compartment #2 (Fig. 2). The smoke curtains were preinstalled in this test according to Figs. 14 a-c. The IR Camera and rain gear were used as well as desmoking procedures. Entrance was from the 01 level starboard side (Fig. 2). Test W-40 had been programmed to study the deployment of curtains during fire fighting. This was not possible as the objectives of fire test W-39 were not met. Thus it was decided to preinstall the smoke curtains in this test. After it was demonstrated that the smoke



MAIN DECK

Figure 14a

Positions of Smoke Curtains
on the main deck for test W-40

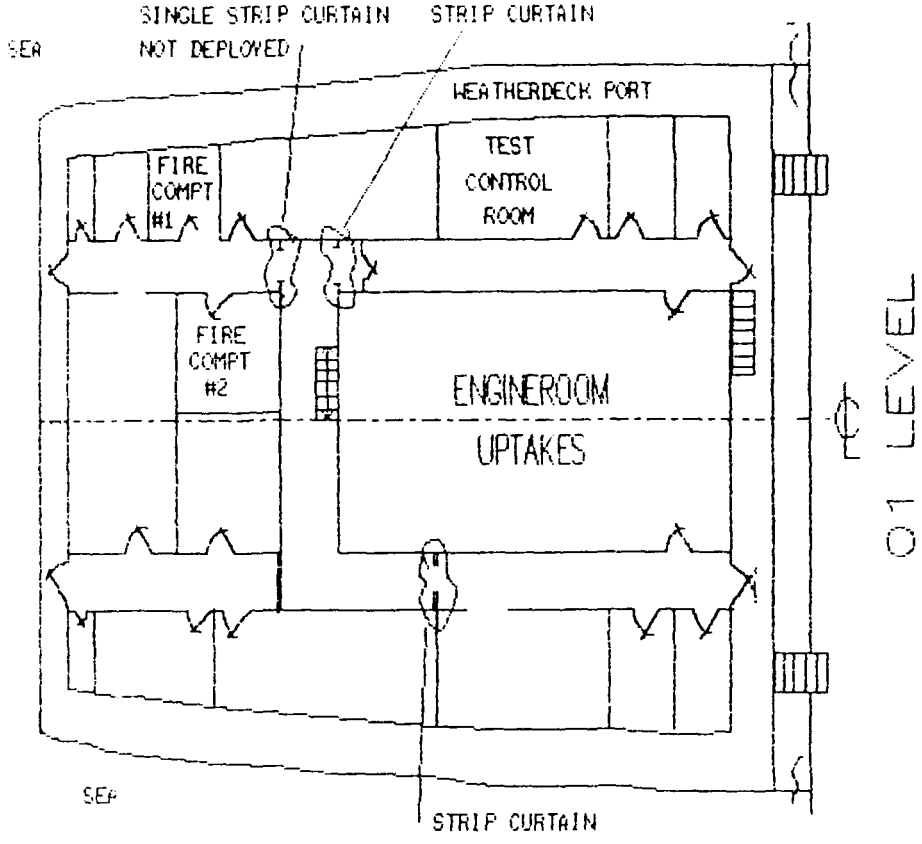


Figure 14b

Positions of Smoke Curtains
on the 01 level for test W-40

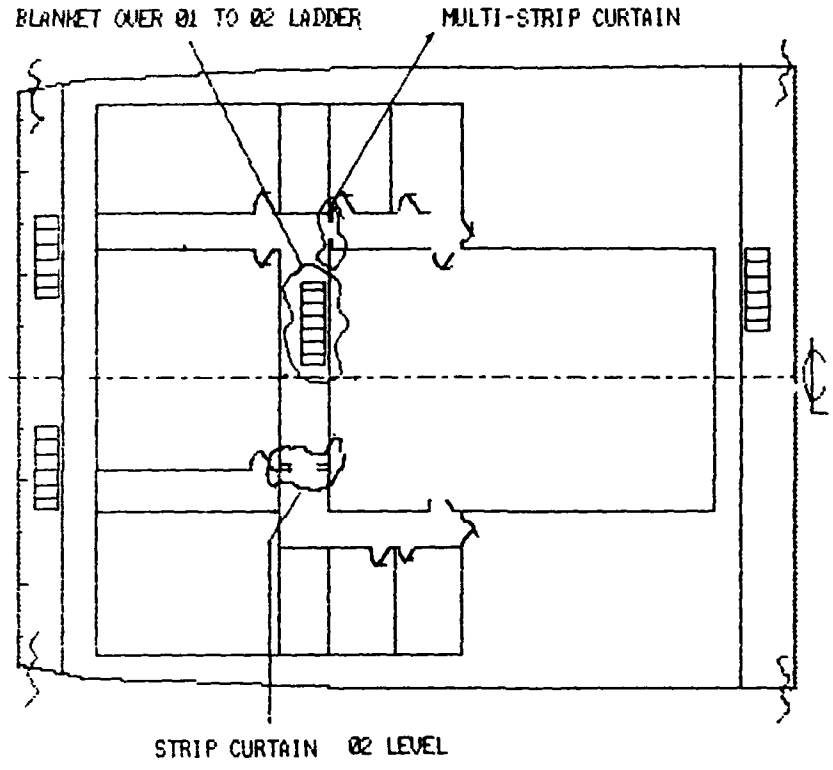


Figure 14c

Positions of Smoke Curtains
on the 02 level for test W-40

curtains significantly contained the smoke, fire fighting was initiated from 01 starboard level and desmoking was accomplished. The main deck starboard passage was left open to weather.

Test W-41 used eight tires and fifteen 3 m (10 ft) lengths of two conductor electrical cable. The fire was in compartment #1 (Fig. 2). Three curtains were on 02 level. A multi-strip curtain was on the portside and an elephant trunk design was on the starboard side. A blanket curtain covered the 01 to 02 ladder (Fig. 14c). There was a blanket curtain on the 01 to main deck hatch (Fig. 14a) and a strip curtain at the archway on the 01 level port side (Fig. 14b). One strip curtain at the starboard archway on 01 level was successfully deployed. The main deck starboard passage was left open to weather. The fire fighters attacked on the 01 level starboard side.

Test W-42 used eight tires and fifteen 3 m (10 ft) lengths of two conductor PVC electrical cable. The fire was in compartment #1 (Fig. 2). The multi-strip curtain on the 02 level portside was left installed except the door on the weatherside of the curtain was left open. The elephant trunk curtain at the thwart ships archway on the 02 level was replaced with a Nomex single strip curtain. The strip curtain on the port passageway 01 level remained as well as the blanket over the 01 to main deck hatch. The curtain on 01 level starboard passageway was installed by the smoke curtain team. The main deck starboard passage was left open to weather. The fire was attacked at the 01 level starboard passage. Once the smoke curtain was deployed on the 01 level starboard passage, desmoking commenced on the non-fire side of the curtain.

Test W-43 used nine tires and fifteen 3 m (10 ft) lengths of two conductor PVC electrical cable. The fire was in compartment #1 (Fig. 2). The multi-strip curtain on the 02 level was left installed (Fig. 14c). Three curtains were deployed in this test: the blanket between 01 and 02 level (Fig. 14c), the strip curtains at the 02 level thwart ships archway (Fig. 14c) and at the 01 starboard archway (Fig. 14b). Both the curtain on the port passageway just outside the test control room (Fig. 14b), and the hatch curtain from the 01 level to main deck (Fig. 14a) were left. Fire fighting was from 01 level and desmoking was carried out on the 02 and 01 levels. The starboard passage on main deck was left open.

Test W-44 used nine tires and fifteen 3 m (10 ft) lengths of two conductor PVC electrical cable. The fire was in compartment #1 (Fig. 2). The multi-strip curtain on the 02 level port side remained installed (Fig. 14c). The three curtains that were deployed in Test-43 were deployed again. An additional curtain closer to the fire was attempted in thwart ships passageway 01 level without success. Desmoking on the

non-fire side of the smoke curtain was accomplished on both the 01 and 02 level. Fire fighters entered on the 01 level starboard side. The main deck starboard door was left open.

RESULTS/DISCUSSIONS

Video Display: The video data were used to determine visibility at the camera locations. This data appears in Appendix A.

Test W-35 The smoke produced by the diesel fuel in Fire compartment #2 quickly reduced visibility on the 01 level port side passage. The smoke spread rapidly up the thwart ships inclined ladder (Figs. 2 & 3) filling the 02 level (Fig. A-1). In fact, the visibility in the 02 level declined more rapidly than in the 01 level fire area. This is not unusual as smoke rises when an access route is available.

Test W-36 The wood crib fire was the hottest of all the fires and initially produced a large quantity of smoke. The amount of smoke diminished with time, allowing visibility to return on the 01 and 02 levels (See Fig. A-2).

Test W-37 The rubber tire fuel produced large quantities of smoke filling both the 01 and 02 levels very rapidly. Smoke did not penetrate the deck (main deck) below the fire deck (01 level) (Fig. A-3). Smoke also did not get by a fixed smoke curtain on the 02 level port passageway. The weather door on the non-smoke side of the curtain was open (Fig. 3).

Test W-38 Smoke from the tires rapidly filled the 01 and 02 levels but very little descended to the main deck (Fig. A-4). Some level of visibility returned on the 01 level starboard side when the weather door was opened for the fire fighters (Fig. A-4). This camera also observed people moving toward the thwart ships passage on the 01 level. Since entry of the firefighters was from the 02 level, this must have been support personnel or fire investigators.

Test W-39 This was the only test in which the smoke penetrated to the main deck. The weather door on the main deck was opened at about 17 minutes, and full visibility returned to the main deck as fresh air fed the fire from below (Fig. A-5). Visibility was rapidly lost on the 01 level portside (fire side) (Fig. A-5).

Test W-40 Smoke curtains were preinstalled in this test. The smoke did not penetrate the main deck (Fig. A-6). Both the curtain over the 01 to 02 ladder in thwart ships

passage and the curtain in starboard passage kept smoke out of the 02 starboard passage (Fig. A-6). The additional curtain in the 02 port passage kept smoke out for 25 minutes. The 01 level rapidly filled with smoke. A portable video on the weather side of the 01 level starboard passage smoke curtain showed smoke was held back.

Test W-41 The three preinstalled curtains on the 02 level did not function the same as in the previous test. The curtain in the 02 port passage held back the smoke. The 01 to 02 ladder curtain and 02 starboard curtain extended the visibility time relative to no curtains. However, the fit was loose enough to allow smoke to get to 02 level and the elephant trunk design did not stop the smoke on the 02 starboard side (Fig. A-7). The blanket design curtain performed well when fitted tightly, but was not successful in any tests. The 01 level filled rapidly (Fig. A-7).

Test W-42 This test was a repeat of W-41, i.e., one curtain was deployed on the 01 level starboard passage. The 01 fire level rapidly filled with smoke. The port side 02 level curtain, as well as 01 to main deck curtain, stopped the smoke. The blanket curtain at 01 to 02 level and the 02 starboard passage curtain impeded the smoke, but did not stop it (Fig. A-8).

Test W-43 The three curtains left in place performed well. Data for two of the curtains are shown in Fig. A-9 (main deck and 02 deck port). The 01 level filled rapidly (01 fantail and 01 deck starboard).

Test W-44 Once again, the curtains left in place performed well (Fig. A-10). The IR cameras once again proved their value. A point worth emphasizing was the value of IR camera to the Damage Control Assistant in viewing mistakes his crews were making which were not observed by the on-scene leader. These mistakes included: falsely identifying fire location by reason of heat, and standing upright in the hot gas, which could have lead to panic, disorientation and heat stress of the fire fighter.

Temperatures: Complete time profiles of temperature for all the tests can be found in Appendix B. Some representative temperatures can be found in Table III. Fig. 9 shows the exact locations of these temperature sensors. When the smoke curtains were used, there was a significant difference in temperatures on the two sides of the curtain. The temperatures in these tests were not as severe as with electrical cable fire fighting tests (2).

Table III - Typical Temperatures on 01 Level

(Channel 61 & 62 port passageway 01, Channel 65 & 66
thwartship passageway 01, Channel 113 & 114, starboard passage way 01)

Test No./ Time, Min:Sec	Temperature °C(°F) Distance from Deck (ft) 6' Channel 61	4' Channel 62	6' Channel 65	4' Channel 66	6' Channel 113	4' Channel 114
W-35/11:15	197(387)	54(129)	127(261)	50(122)	46(115)	36(97)
W-36/15:04	220(428)	82(180)	135(275)	97(207)	72(162)	46(115)
W-37/15:04	126(259)	48(118)	93(199)	53(127)	41(106)	34(93)
30:05	169(336)	79(174)	121(250)	86(187	58(136)	47(117)
W-38/15:04	223(433)	97(207)	136(277)	110(230)	68(154)	49(120)
30:05	170(338)	64(147)	121(250)	71(160)	57(135)	43(109)
W-39/15:05	235(455)	73(163)	133(271)	77(171)	51(124)	30(86)
30:05	167(333)	67(153)	120(248)	64(147)	52(126)	31(88)
W-40/15:04	97(207)	54(129)	73(163)	63(145)	27(81)	26(79)
30:15	100(212)	60(140)	79(174)	63(145)	31(88)	28(82)
W-41/15:05	184(363)	49(120)	114(237)	46(115)	25(77)	24(75)
30:05	67(153)	51(124)	67(153)	43(109)	26(79)	25(77)
W-42/15:05	136(277)	54(129)	76(169)	60(140)	32(90)	28(82)
30:05	130(266)	63(145)	83(181)	70(158)	31(88)	26(79)
W-43/15:05	124(255)	36(97)	70(158)	38(100)	22(72)	22(72)
30:05	73(163)	51(124)	88(190)	52(126)	25(77)	23(73)
W-44/15:05	91(196)	43(109)	58(136)	47(117)	28(82)	29(84)
30:05	55(131)	44(111)	51(124)	45(113)	28(82)	28(82)

Gas Compositions: Gas compositions for the tests can be found in Appendix C. Figs. 11-13 show the locations of the gas sampling points. Oxygen, carbon monoxide and carbon dioxide were monitored. Significant problems with the gas analyzers were experienced. Table IV lists the analyzers that were not operable during specific tests.

Visibility: Appendix A gives the visibility as a function of time for the tests. The data show that when the top half of the passage is blocked by the curtains the spread of smoke was very effectively stopped. The blanket over the 01 to 02 hatch significantly impeded the smoke spread to the 02 level. The deployment of smoke curtains during a fire allowed previously smoke filled areas to be rapidly desmoked while fire fighting efforts were still in progress. There was no evidence that active desmoking on the non-fire side of the smoke curtain caused the fire to grow. Photographs of test scenes are shown in Appendix D.

CONCLUSIONS

The concept of the portable smoke curtains limits, but does not totally prevent, the migration of smoke from and the flow of oxygen to the fire. Limiting the migration of smoke allows tighter containment and control of a fire area, reduces the difficulty in investigating for other damage and allows concurrent access for damage repairs in an area where there would be no visibility otherwise. Limiting the flow of oxygen to the fire seat with smoke curtains reduces the intensity of the fire and reduces resultant damage. While it may appear unnecessary to install smoke curtains at weather deck accesses, the curtains would serve the purpose of limiting oxygen to the fire.

Once fire/smoke boundaries are established with the curtains, improvement in visibility can be further enhanced by desmoking with blowers on the non-fire side of the curtain. If the initial smoke boundaries were established at a distance from the fire that is not as close as desired or as close as later becomes possible, it may be advisable to establish a new boundary closer to the fire. When new smoke boundaries are established with the portable curtains, the old boundary then becomes the secondary fire/smoke boundary and the area may be desmoked without feeding fresh air to the fire.

RECOMMENDATIONS

There are no hard and fast rules which should dictate exactly where, when or how to install smoke curtains. Common sense developed from experience, should determine the plan for deploying smoke curtains. As in most aspects of fire fighting, the on scene decisions should be based on the situation at hand. It would not be advisable to install smoke curtains for a fire which is readily accessible and visible, and which could probably be extinguished rapidly. However, if in doubt, smoke

Table IV - Inoperable Gas Analysis

Test	Anal.	Location	Channel
W-35	CO_2	02 Level	34
	O_2	Main Deck	31
W-36	O_2	Main Deck	31
	O_2	02 Level	33
W-37	CO	01 Level Starboard Pass	25
W-38	O_2	Main Deck	31
		02 Level	33
W-39	CO_2	Fire Room	18
	CO	Fire Room	17
	CO	01 Level Starboard	25
	O_2	Fire Room	16
	O_2	Main Deck	31
	O_2	02 Level	33
W-40	O_2	01 Level Starboard	24
	O_2	Main Deck	31
	O_2	02 Level	33
W-41	CO_2	01 Level Starboard	26
	CO_2	01 Level Port	28
	CO_2		
	CO	01 Level	25
	O_2	01 Level Starboard	24
	O_2	01 Level Port	27
	O_2	01 Level Starboard	29
	O_2	Main Deck	31
	O_2	02 Level	33
W-42	CO_2	01 Level Starboard	30
	CO_2	01 Level Starboard	25
W-43	CO	01 Level Starboard	25
W-44	CO	01 Level Starboard	25

curtain installation should commence. Since smoke curtains do not unduly hamper investigators or fire fighters, their installation should not be delayed to await personnel who may eventually need to gain access. Fire fighters and investigators should not wait for smoke curtain installation nor should the smoke curtain team await fire fighters and investigators. All teams should proceed with their assignments as soon as possible (preferably concurrently).

Once a smoke curtain/blanket is installed for the control of smoke, a man should be assigned to maintain a watch on it (at the "clean" side). His duties would include maintaining a tight seal, assisting personnel during transit, maintaining boundary integrity for fire and smoke and relaying required verbal communication while keeping the on-scene leader aware of conditions.

Should the fire spread and the fire/smoke boundary become threatened, cooling the curtain with water as would be done for a fire boundary should prove effective. If the fire/smoke boundary should become untenable, the procedure for abandoning would be the same as abandoning a fire boundary - the establishment of a new boundary.

Smoke Curtain Availability - Portable smoke curtains and attaching devices should be stored in each repair locker. The number would depend on class of ship.

Portable smoke curtains should be available for doorways (watertight and joiner), archways and unplanned industrial accesses or holes from enemy action. Portable smoke blankets should be available to cover hatchways and holes in the deck.

Smoke Curtain Team Assignment - The smoke curtain team could be composed of those personnel who would normally be assigned and equipped as fire boundary watches. Fire boundaries can only be established effectively where there is adequate visibility. Effectively installed smoke curtains improve visibility in areas close to the fire; therefore smoke boundaries (if established) become in fact the closest possible fire boundaries.

While Damage Control Central is responsible for determining the location of fire/smoke boundaries, initial action should not be delayed awaiting these orders. Rapid and effective installation is critical if they are to perform as designed. Smoke boundaries should be established as close as practical to the seat of the fire.

REFERENCES

1. Williams, F. W., "Navy Smoke Curtain Tests, October 3-11, 1986," NRL Ltr Rpt 6180-994 of 17 Sept 86.

2. Williams, F. W., "Full Scale Cable Fire Tests at U.S. Coast Guard, Fire and Safety Test Detachment, Mobile, AL," NRL Ltr Rpt 6180-699 of 5 Sept 85.

APPENDIX A

Visibility Measurements for Various Tests

The plots presented in this appendix were constructed by viewing the video tapes from the smoke curtain tests. The visibility at time zero depicts the distance of the furthermost light bulb or some other object in the passageway not necessarily how far one could see. It is to be used as a frame of reference. The most critical data is the point where visibility was diminished and how rapidly. For instance, for Test W-35, the visibility was lost on the deck above the fire before it was lost in the fire passageway. This is not unusual as hot smoke rises and enters levels above.

Fig. A-1 Visibility of selected video cameras on Main Deck, 01 and 02 levels during test W-35

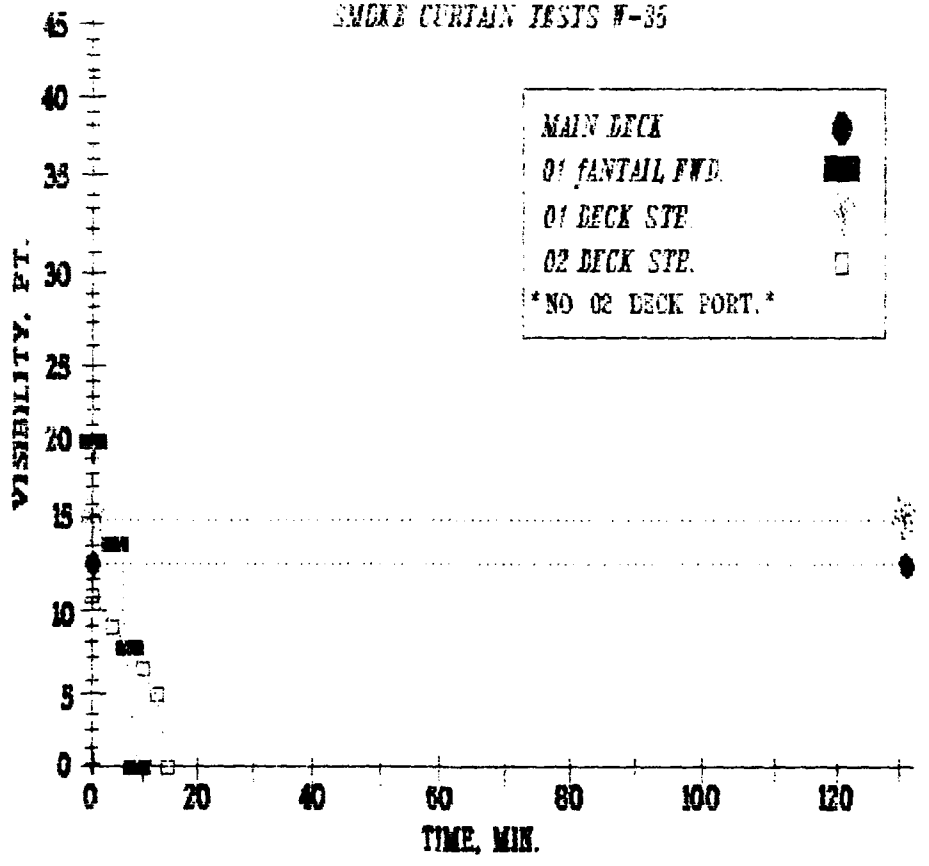


Fig. A-2 Visiblity of selected video cameras on Main Deck, 01 and 02 levels during test W-36

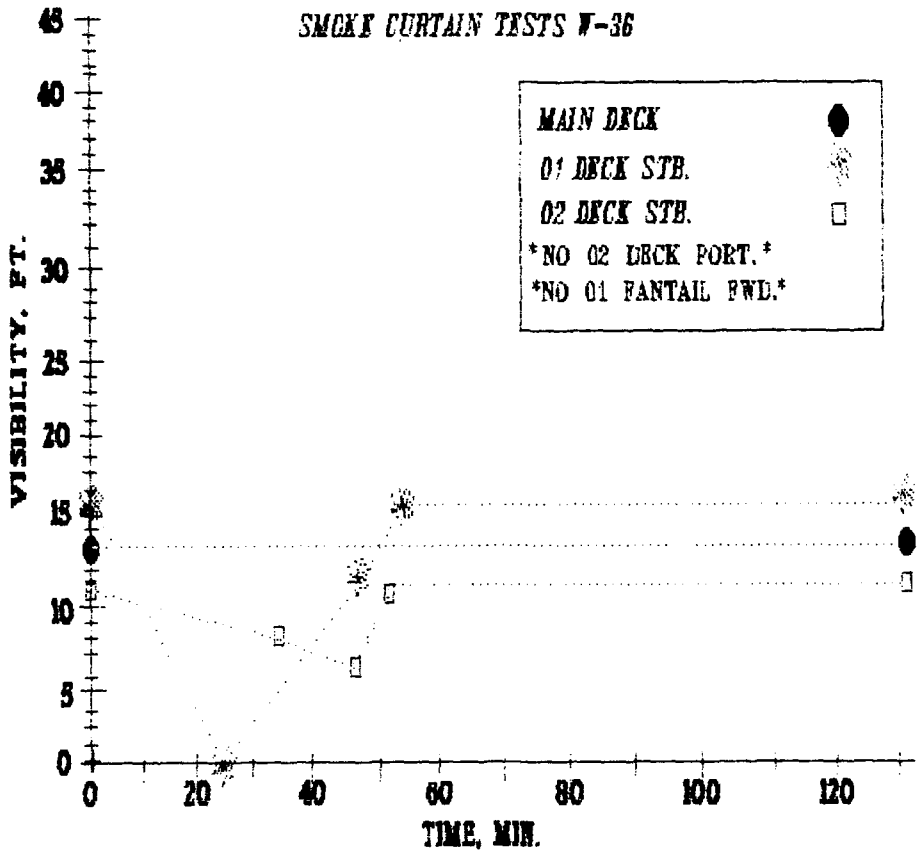


Fig. A-3 Visibility of selected video cameras on Main Deck, 01 and 02 levels during test W-37

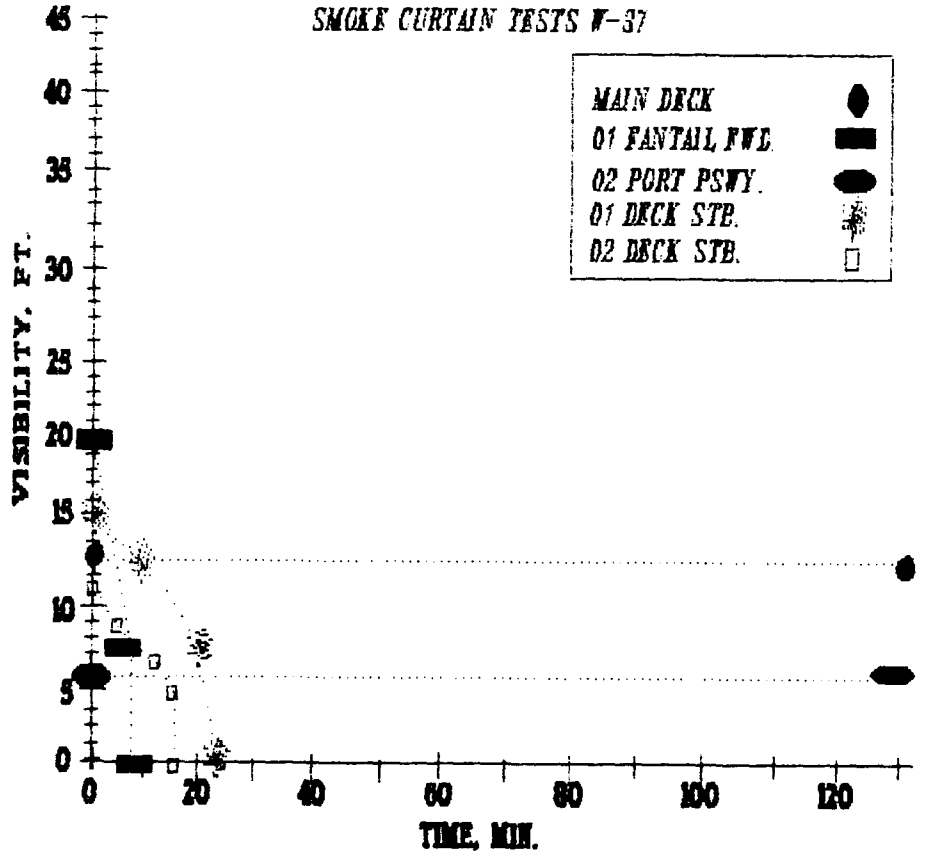


Fig. A-4 Visibility of selected video cameras on Main Deck, 01 and 02 levels during test W-38

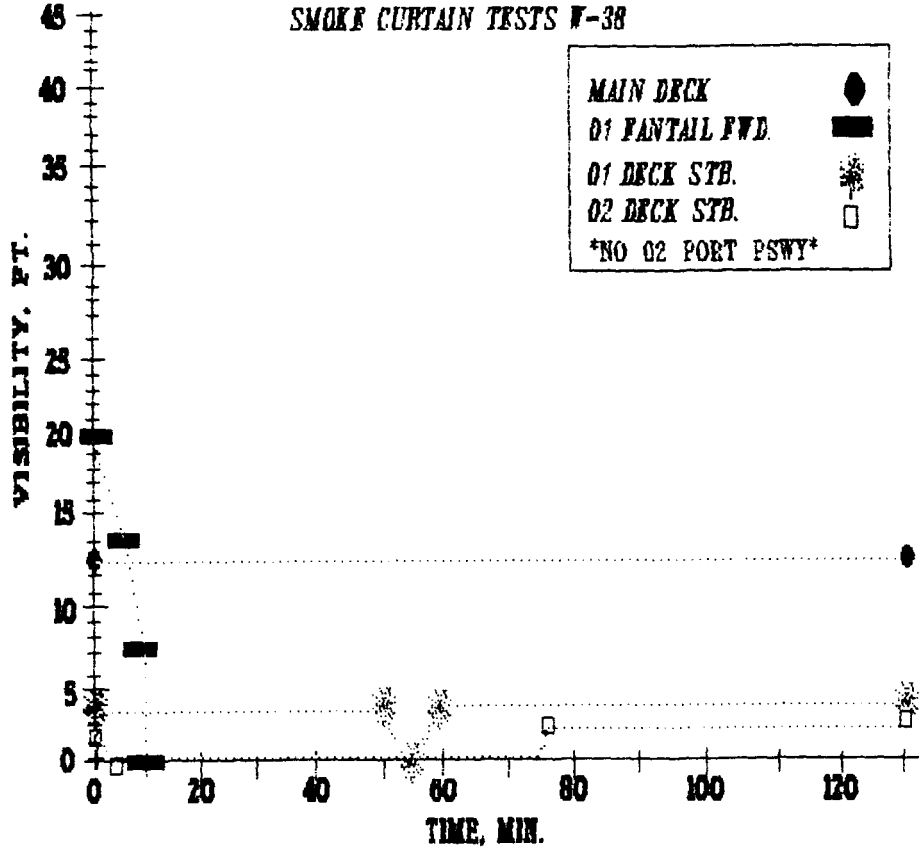


Fig. A-5 Visibility of selected video cameras on Main Deck, 01, and 02 levels during test W-39

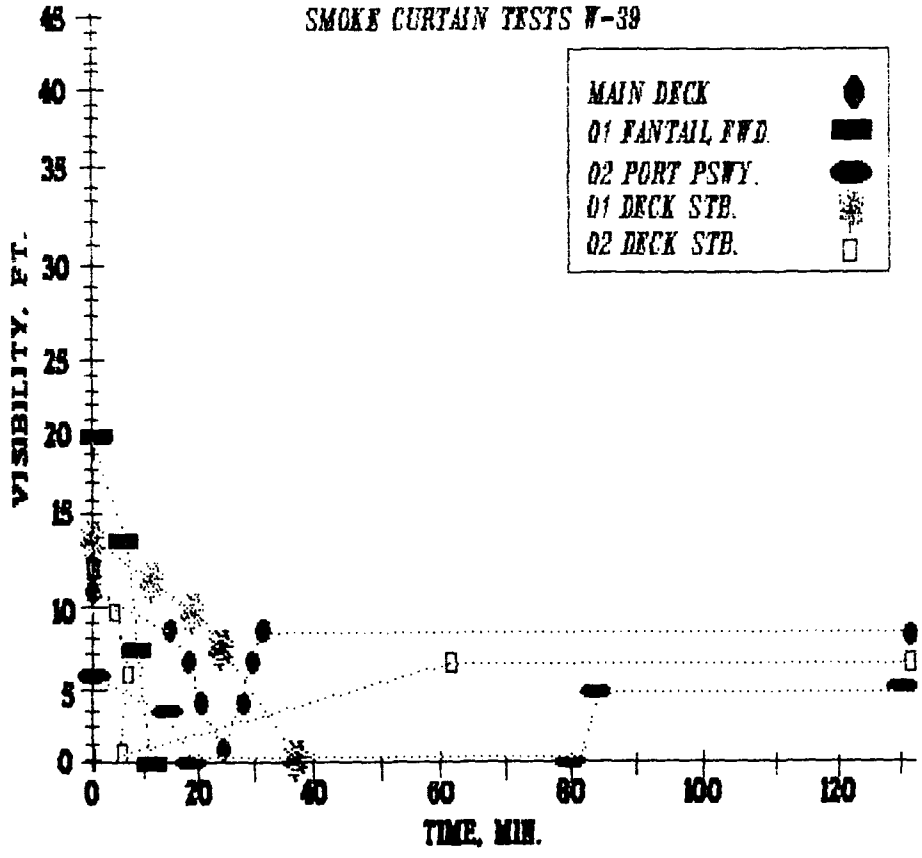


Fig. A-6 Visibility of selected video cameras on Main Deck, 01 and 02 levels during test W-40

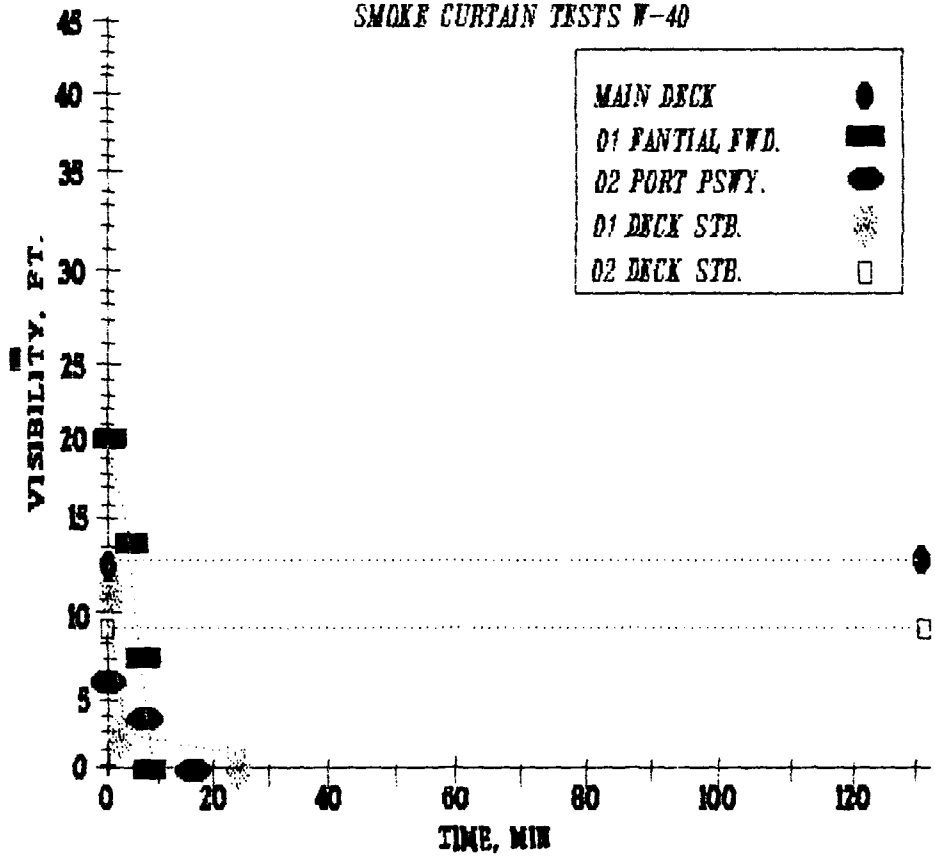


Fig. A-7 Visibility of selected video cameras on Main Deck, 01 and 02 levels during test W-41

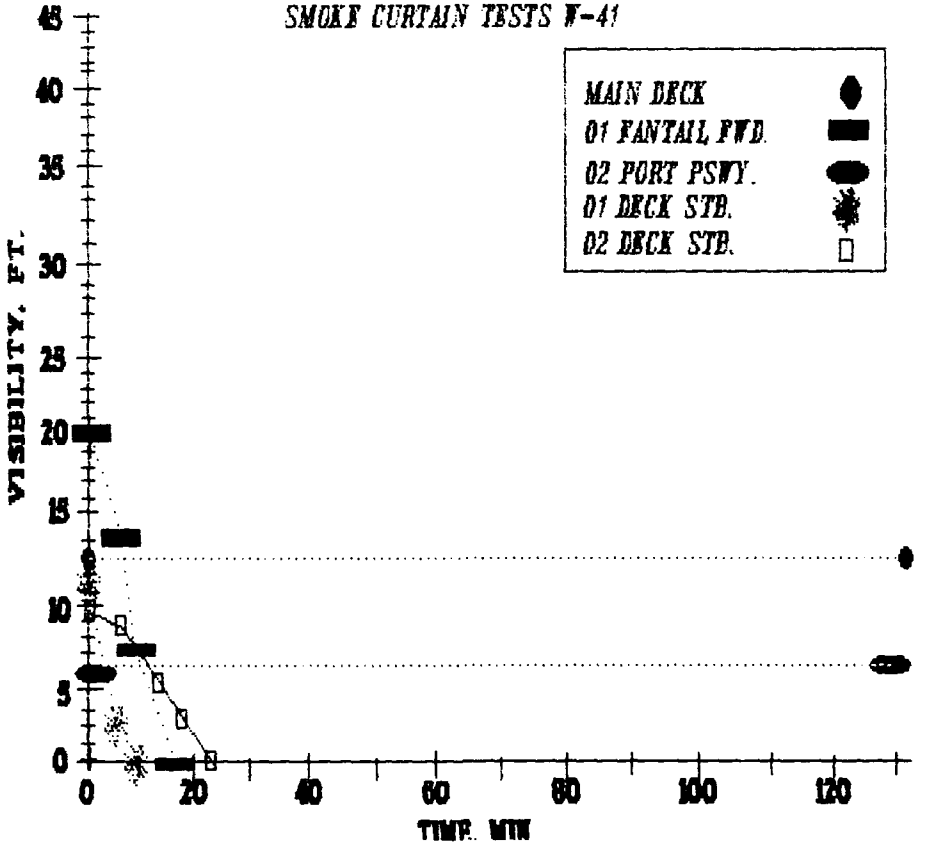


Fig. A-8 Visibility of selected video cameras on Main Deck, 01 and 02 levels during test W-42

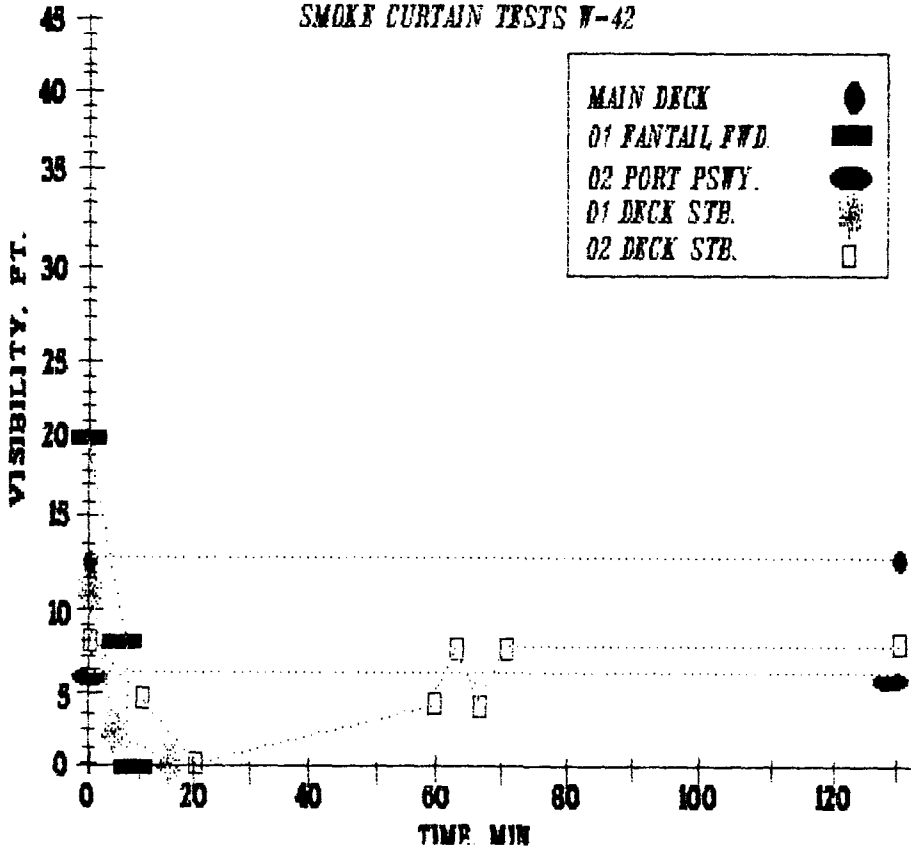


Fig. A-9 Visibility of selected video cameras on Main Deck, 01 and 02 levels during test W-43

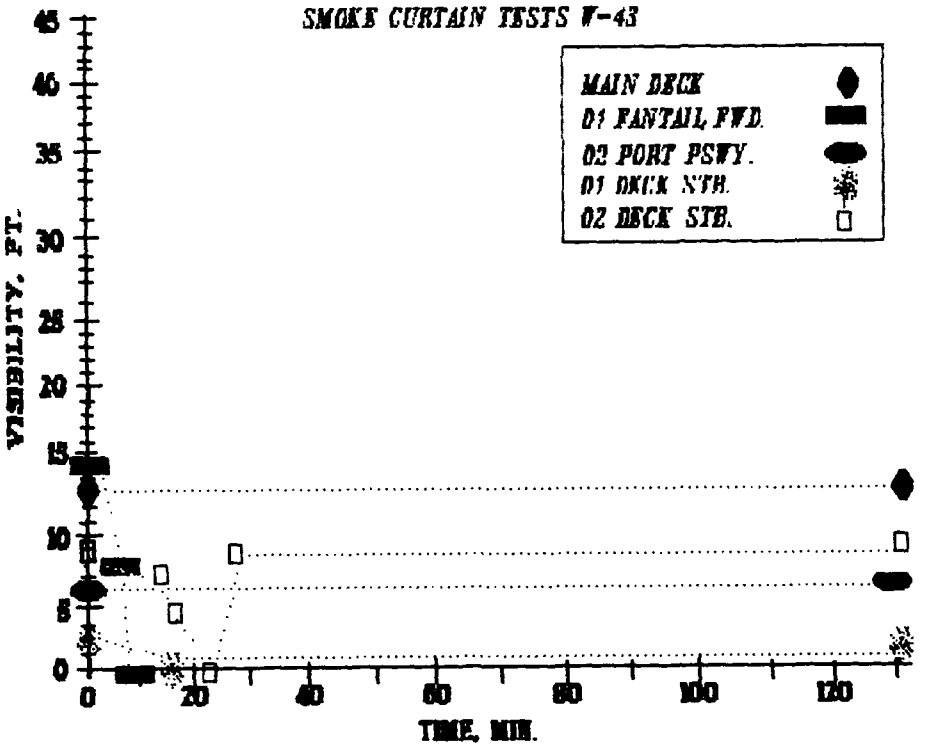
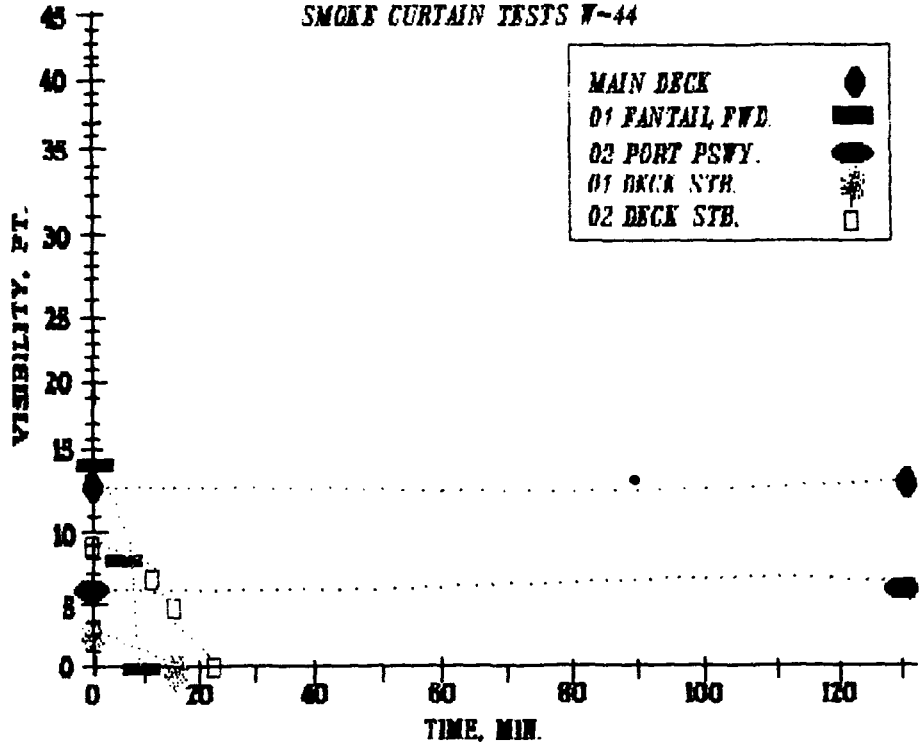


Fig. A-10 Visibility of selected video cameras on Main Deck, 01 and 02 levels during test W-44



APPENDIX B

Temperature Profiles for Various Tests

Fig. B-1 SMOKE CURTAIN TEST W-35 LEVEL 02 CH 116 O, 117 X, 118 +, 119 ✳

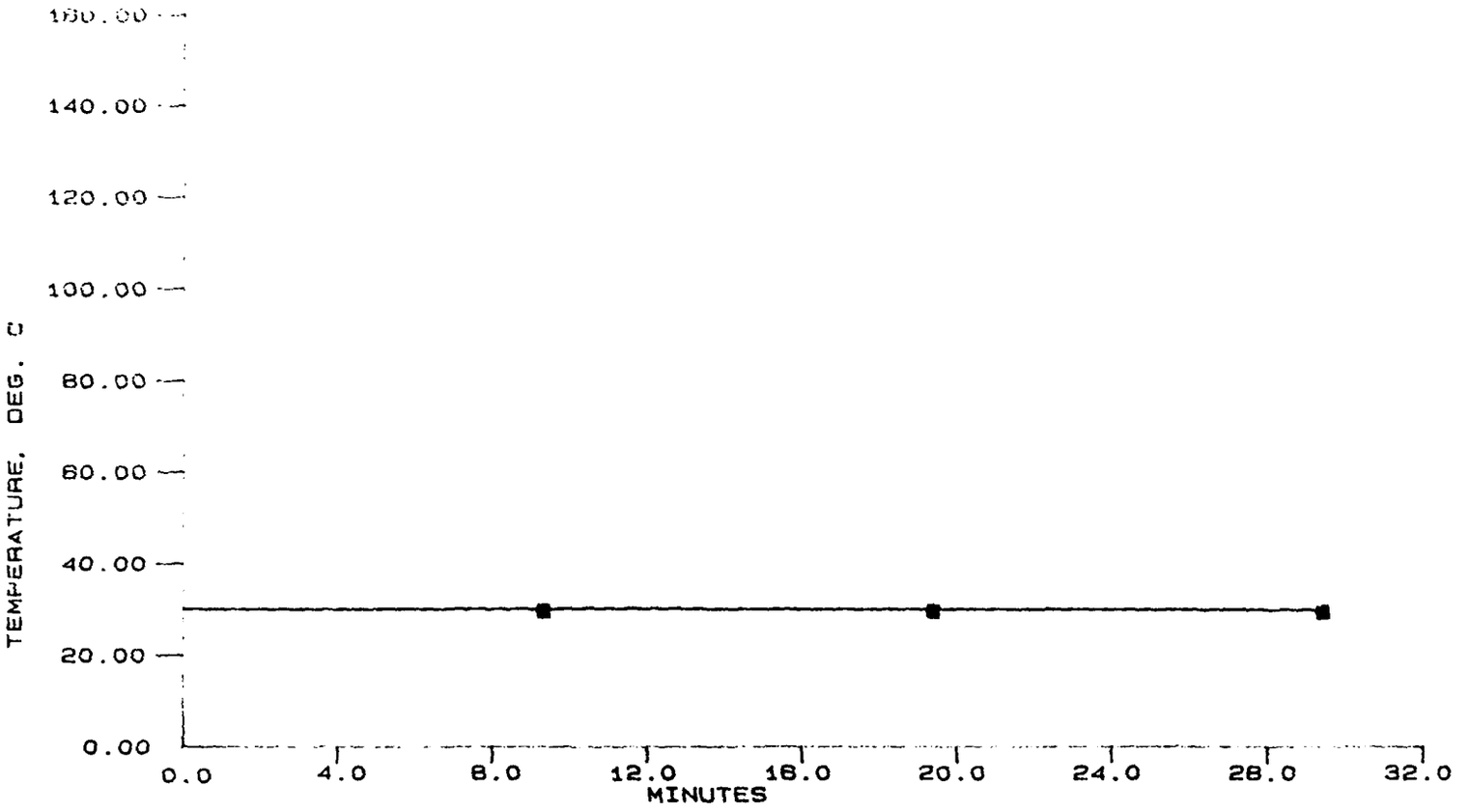


Fig. B-2 SMOKE CURTAIN TEST W-35 LEVEL 02 CH 56 ○ .57 X .58 + .59 ✳

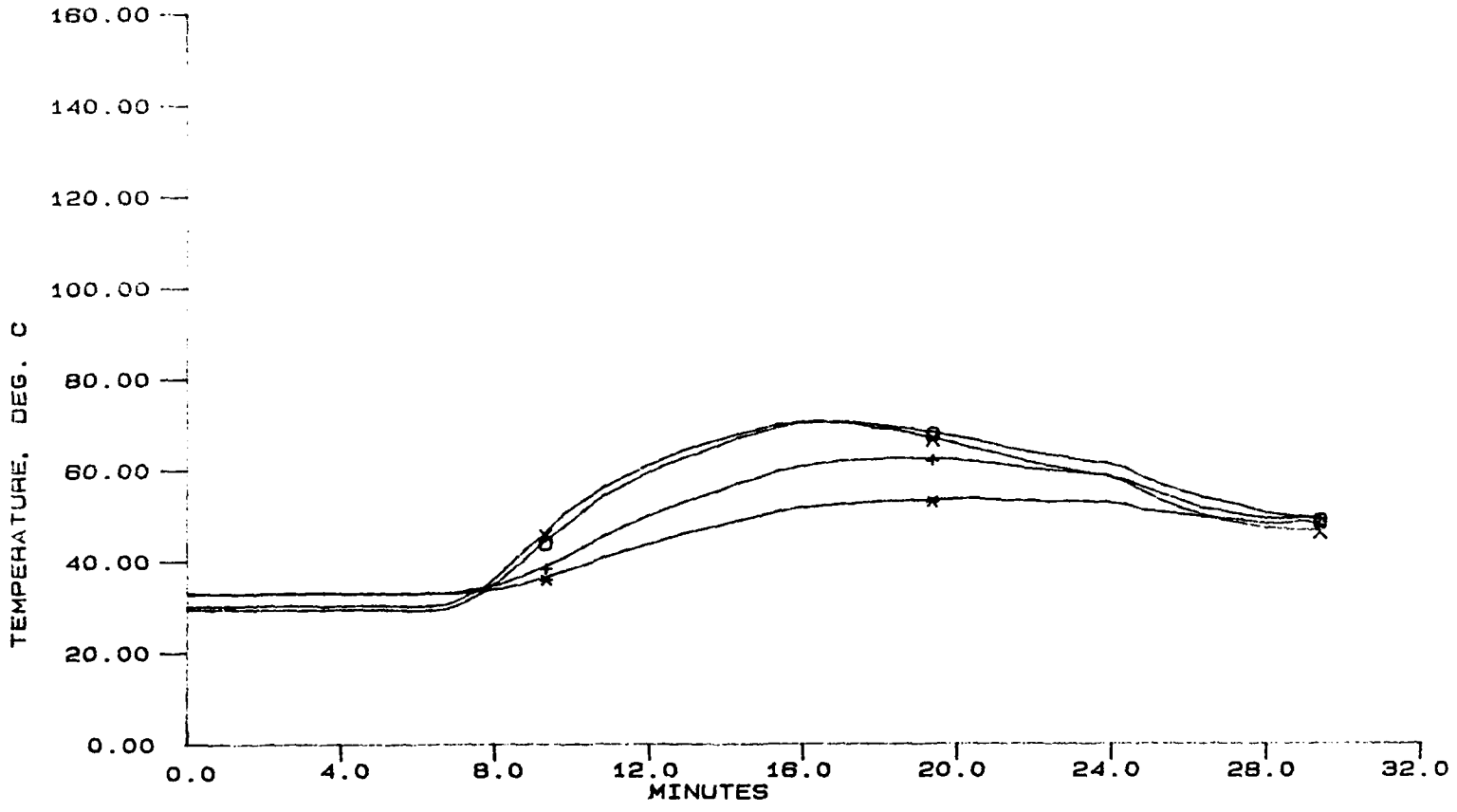


Fig B-3 SMOKE CURTAIN TEST W-35 LEVEL 02 CH 52 ○ , 53 × , 54 + , 55 ✳

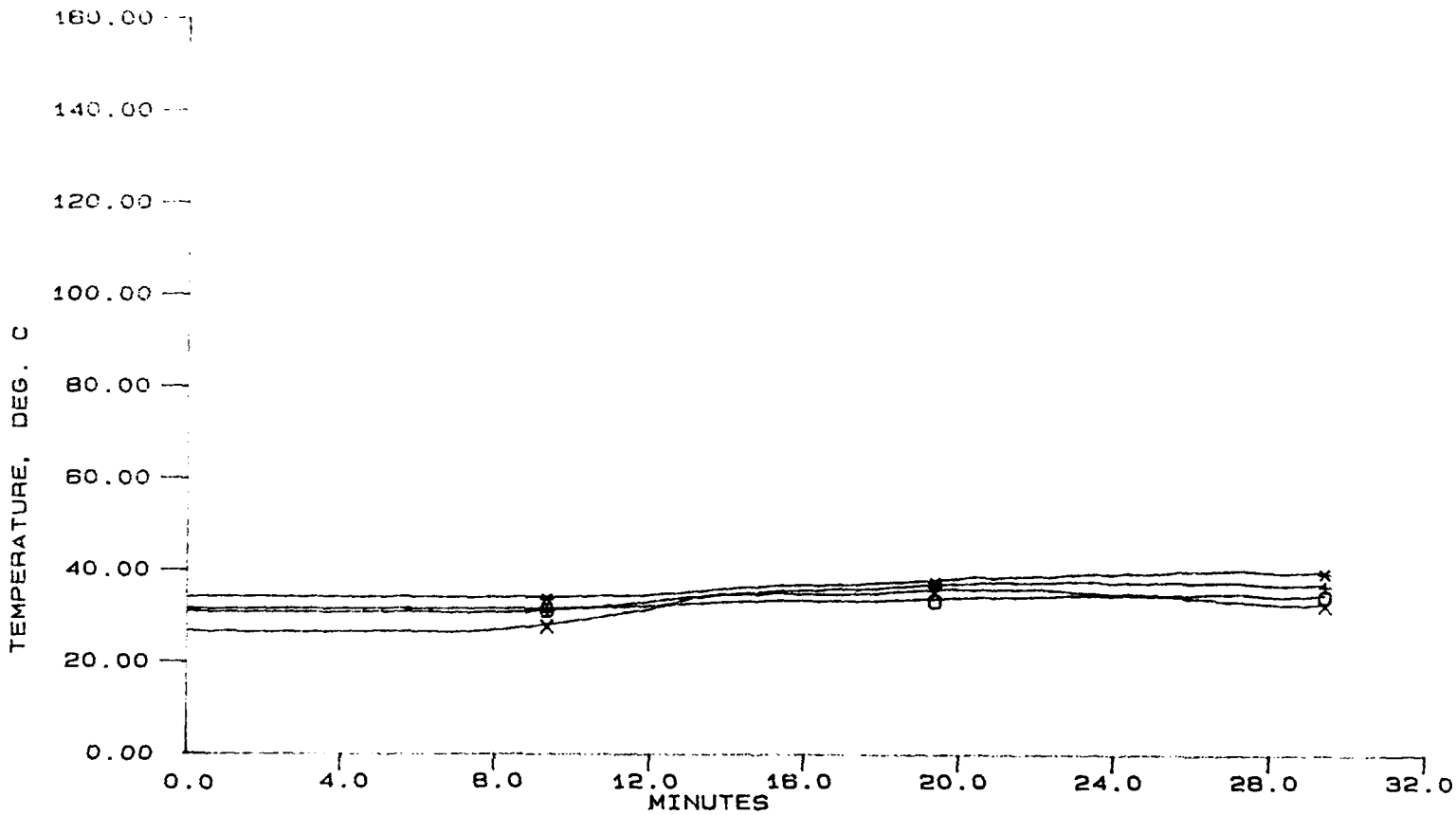


Fig. B-4 SMOKE CURTAIN TEST W-35 LEVEL 02 CH 48 O , 49 X , 50 + , 51 ✳

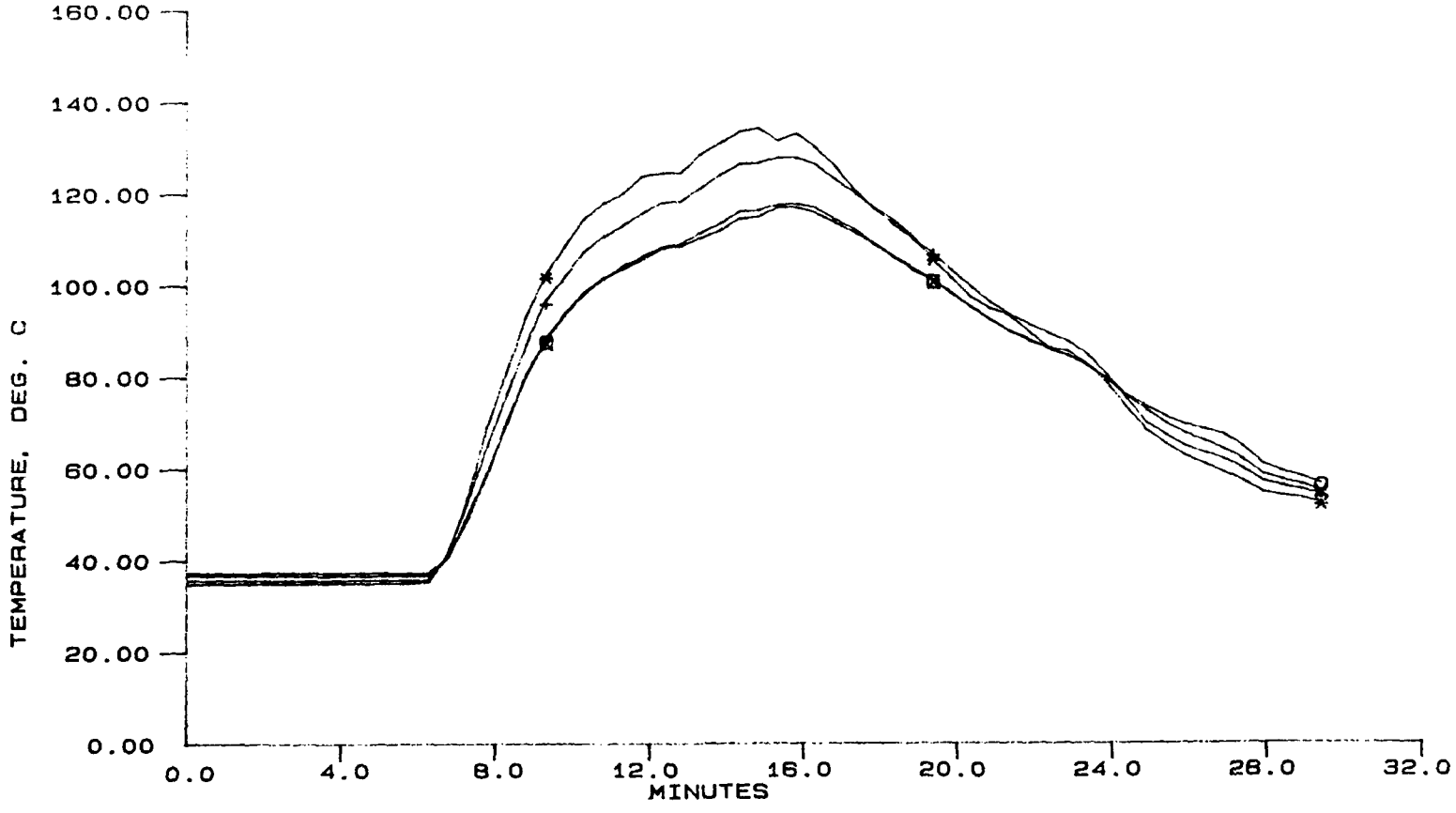


Fig. B-5 SMOKE CURTAIN TEST W-35 LEVEL 02 CH 44 ○ , 45 X , 46 + , 47 ✳

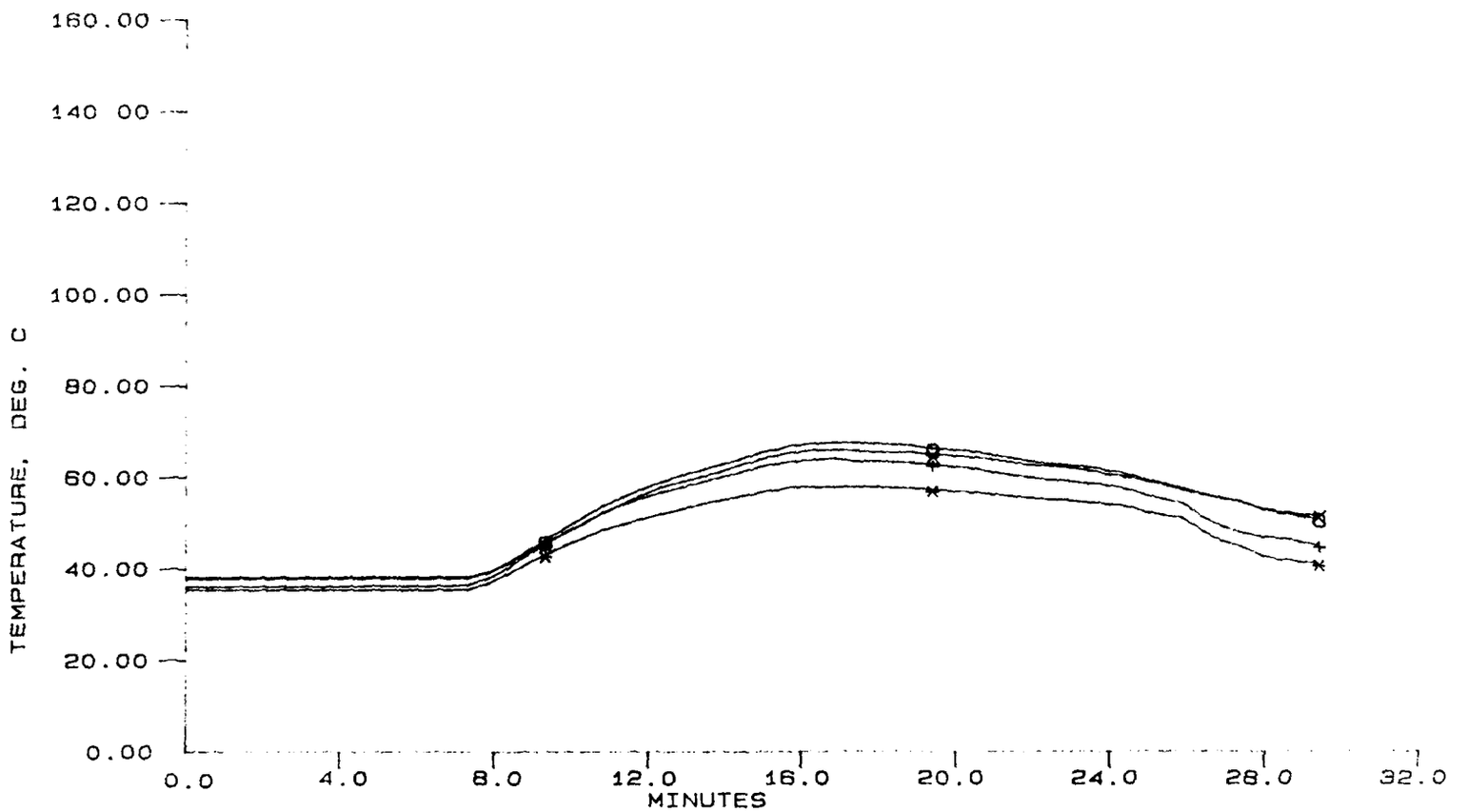


Fig. B-6 SMOKE CURTAIN TEST W-35 LEVEL 01 CH 72 73 74 75

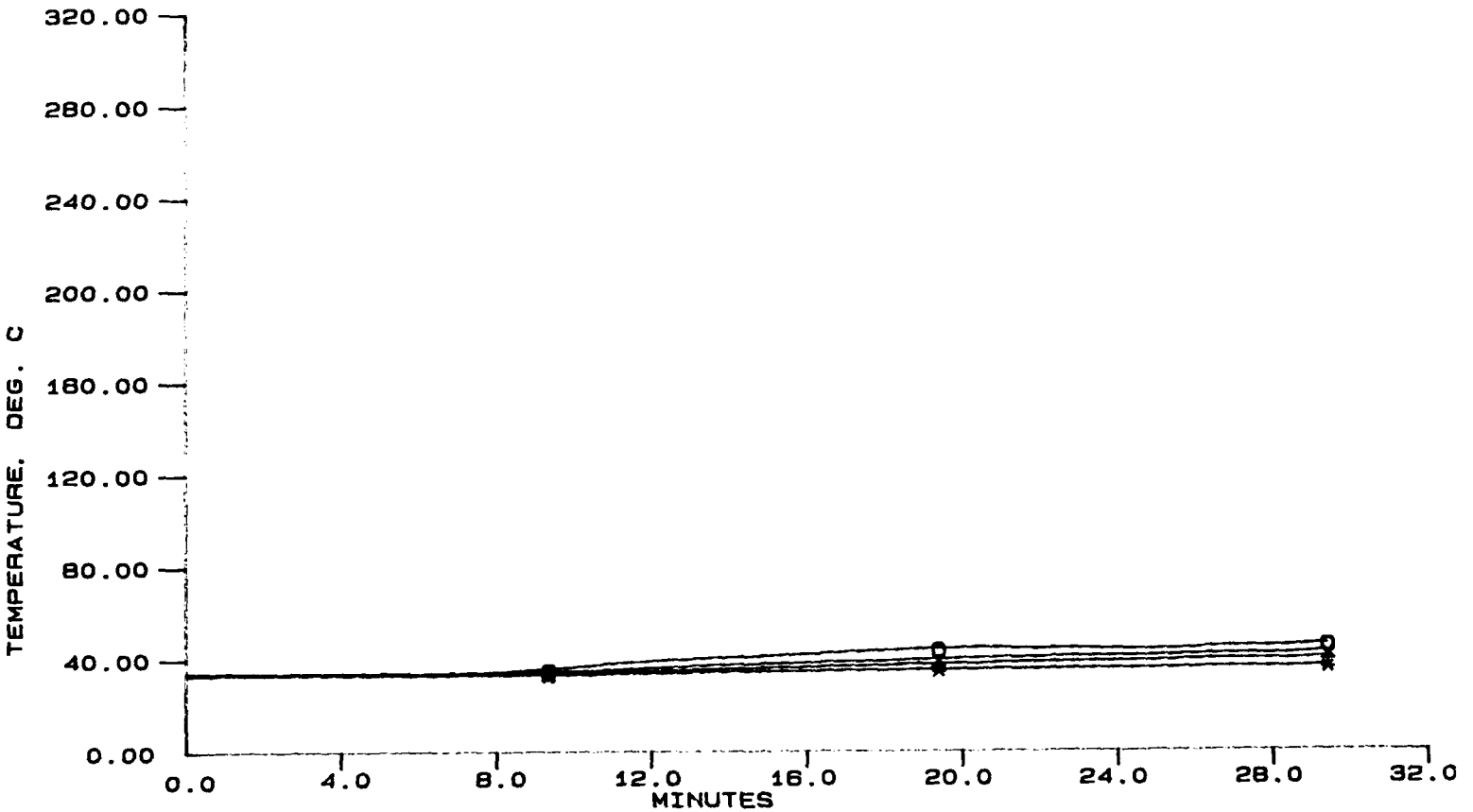


Fig. B-7 SMOKE CURTAIN TEST W-35 LEVEL 01 CH 64 65 66 67

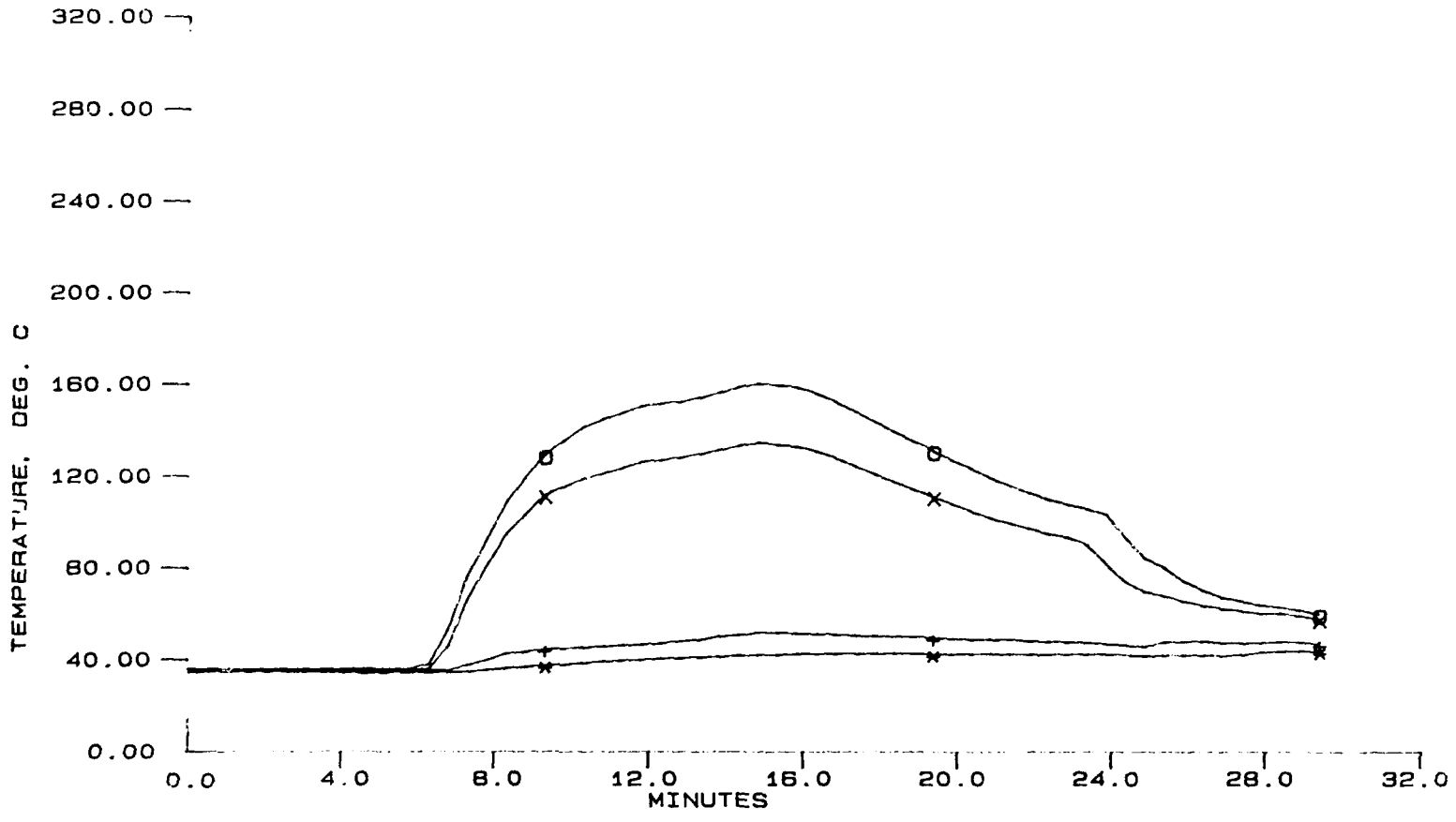


Fig. B-9 SMOKE CURTAIN TEST W-35 LEVEL 01 CH 60 61 62 63

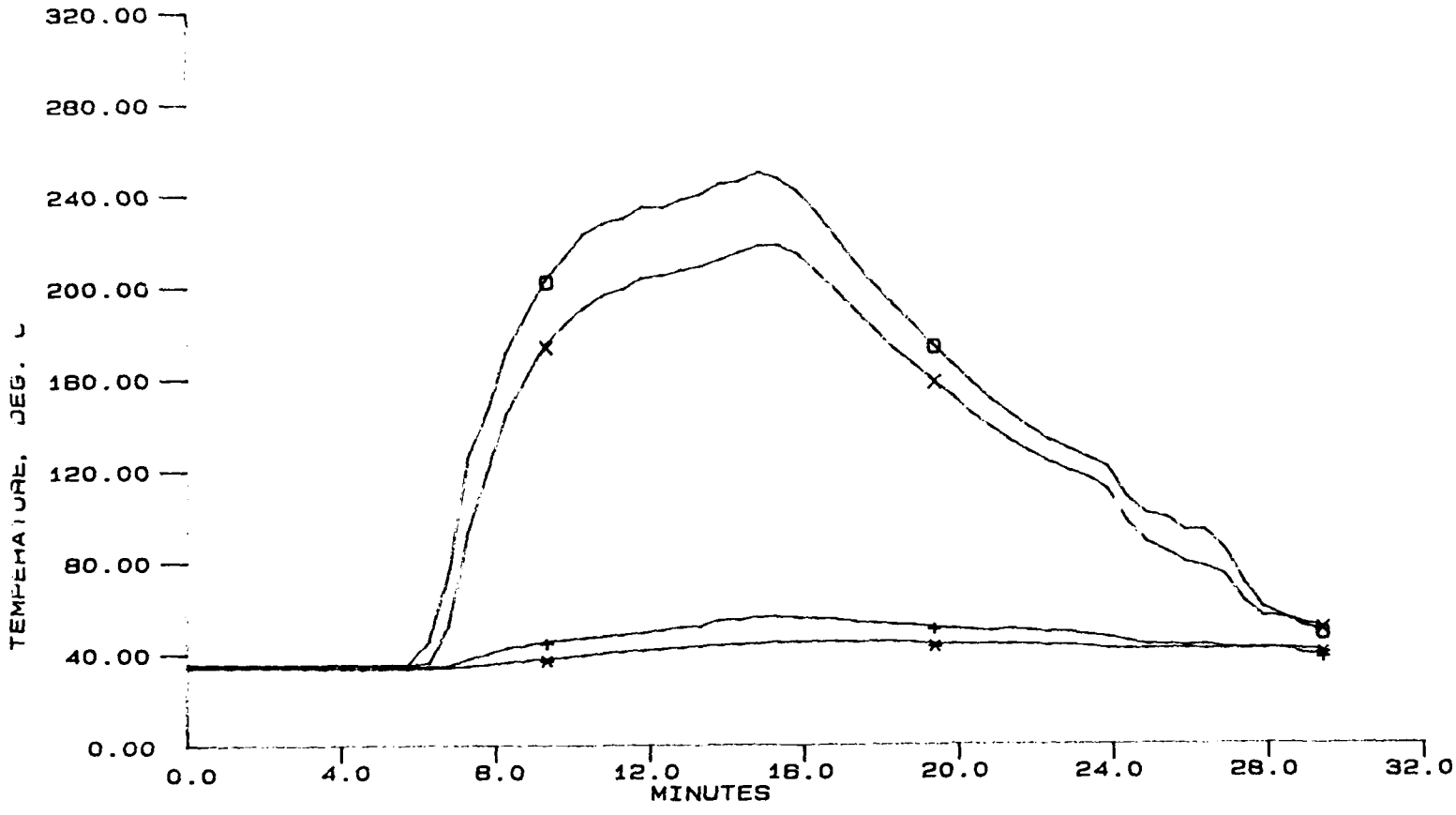


Fig. B-9 SMOKE CURTAIN TEST W-35 LEVEL 01 CH 68 69 70 71

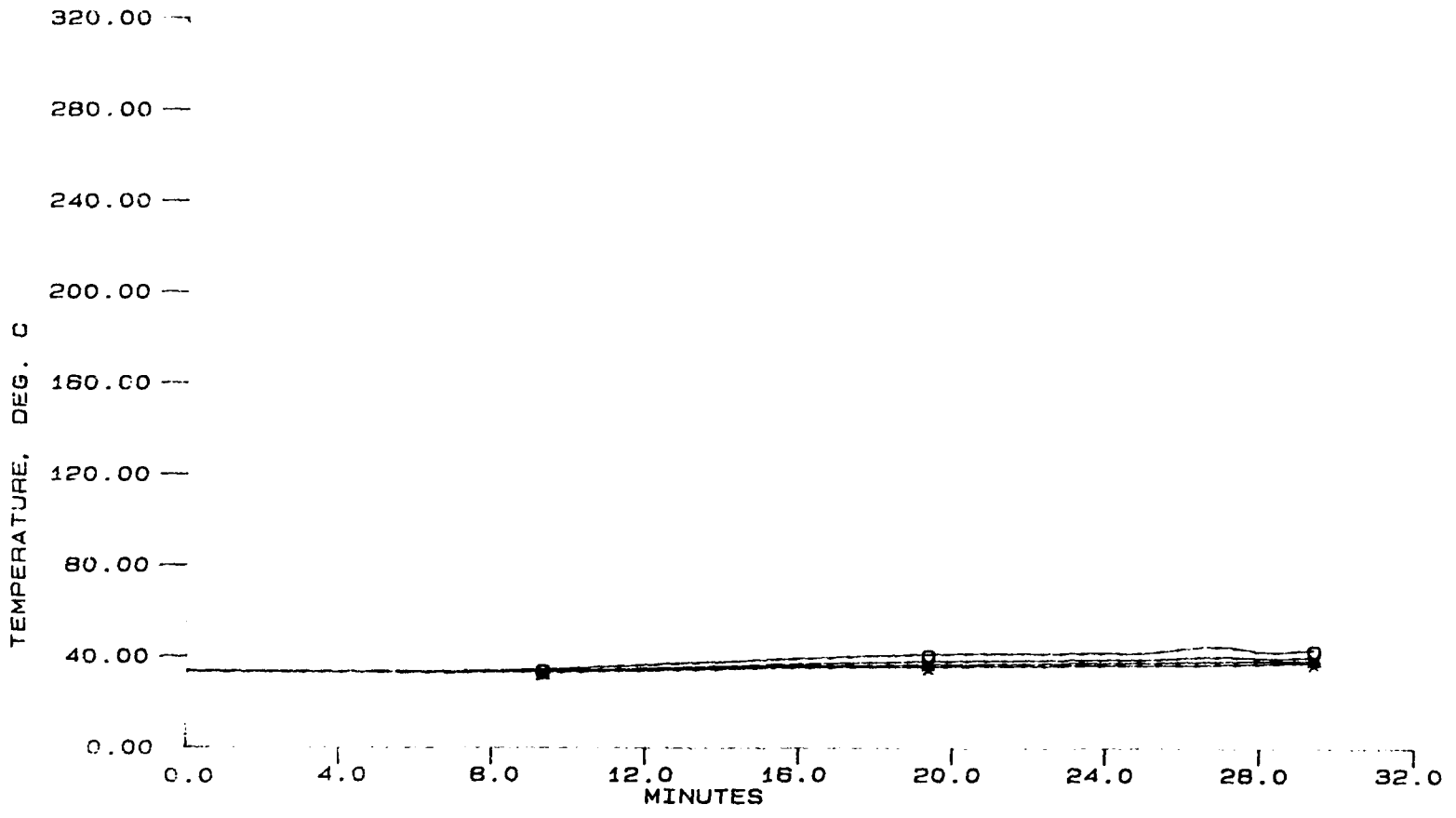


Fig. B-10 SMOKE CURTAIN TEST W-35 LEVEL 01 CH 112 113 114 115

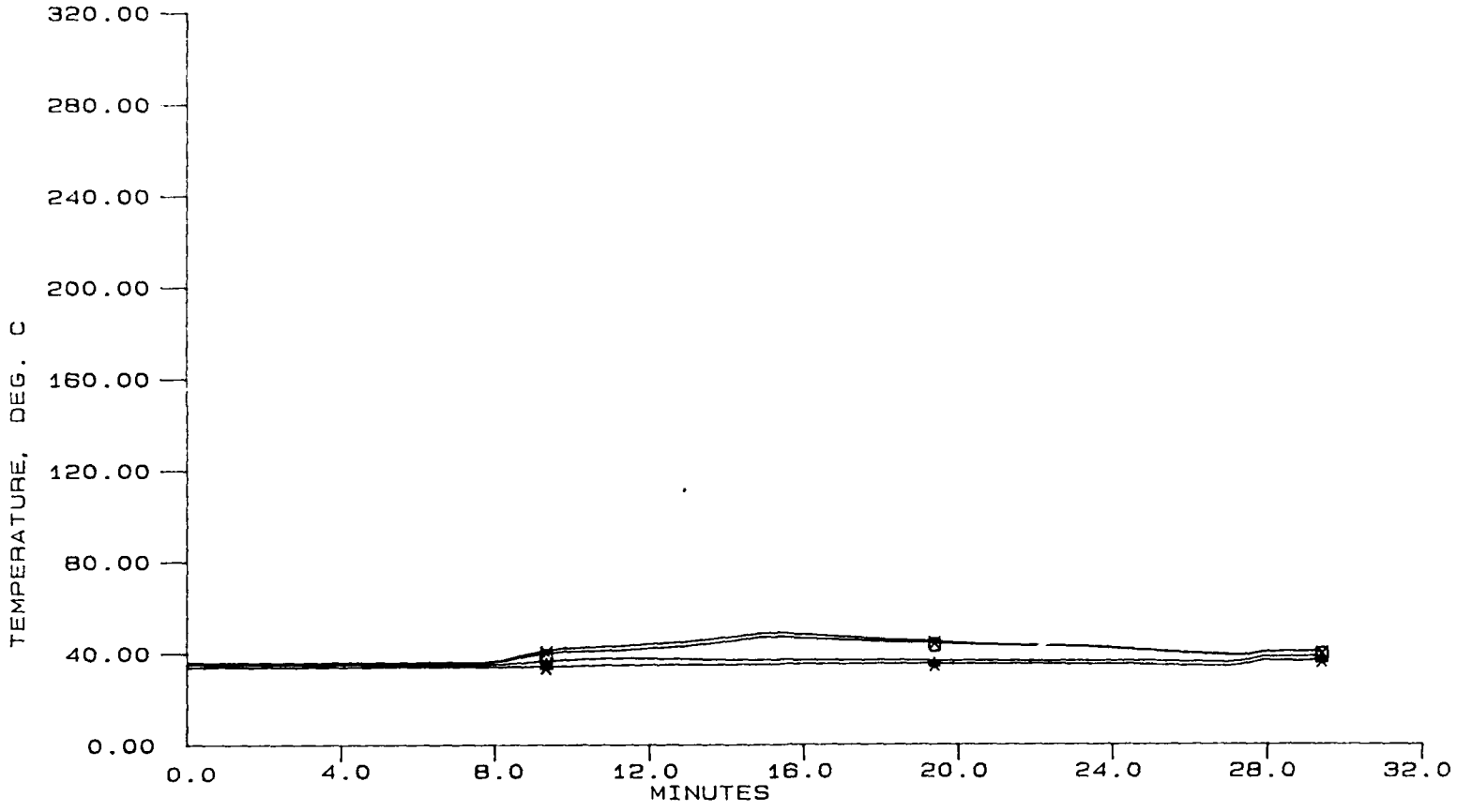


Fig. B-11 SMOKE CURTAIN TEST W-35 LEVEL 01 CH 76 77 78 79

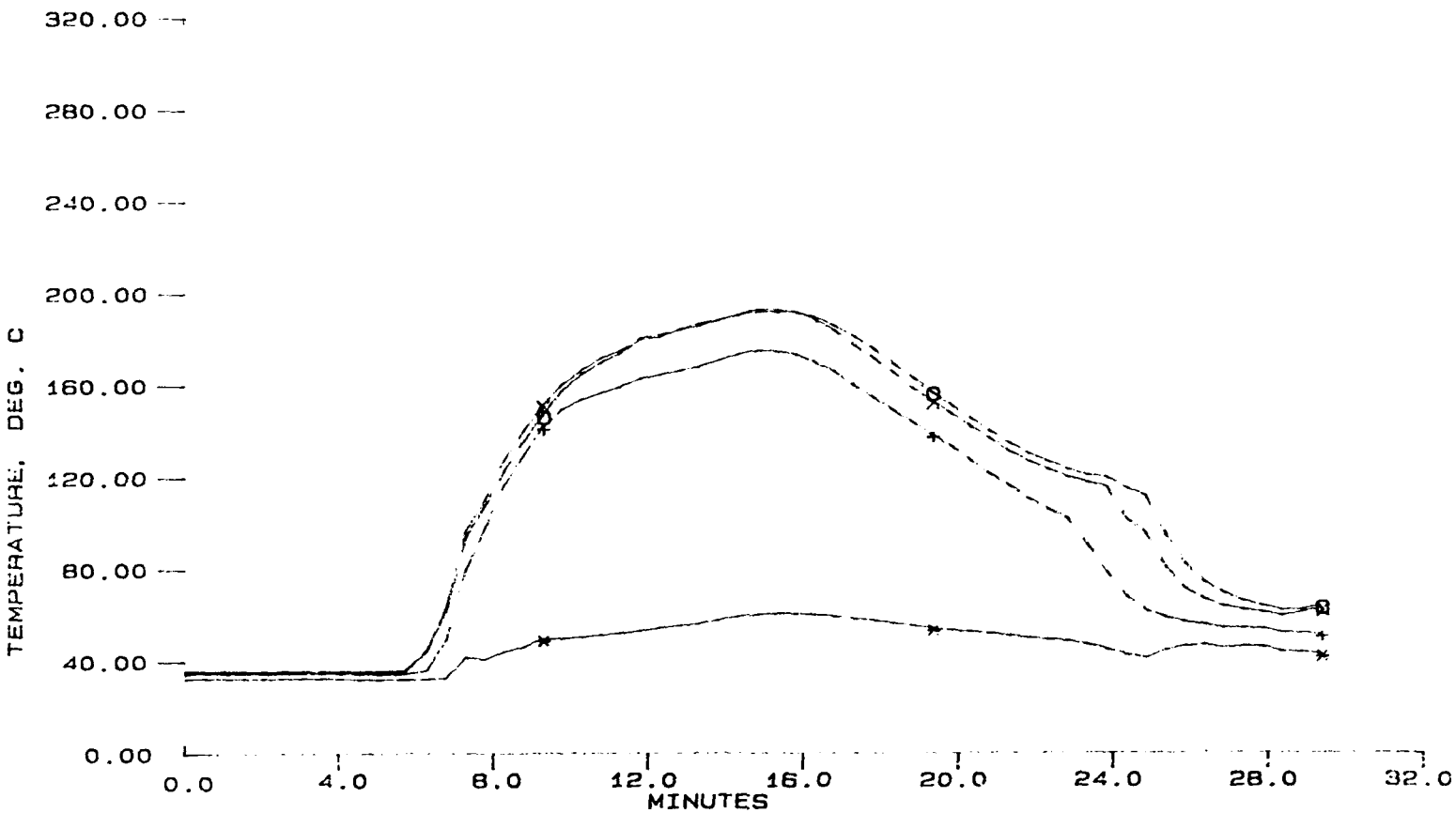


Fig. B-12SMOKE CURTAIN TEST W-35 LEVEL 01 CH 80 81 82 83

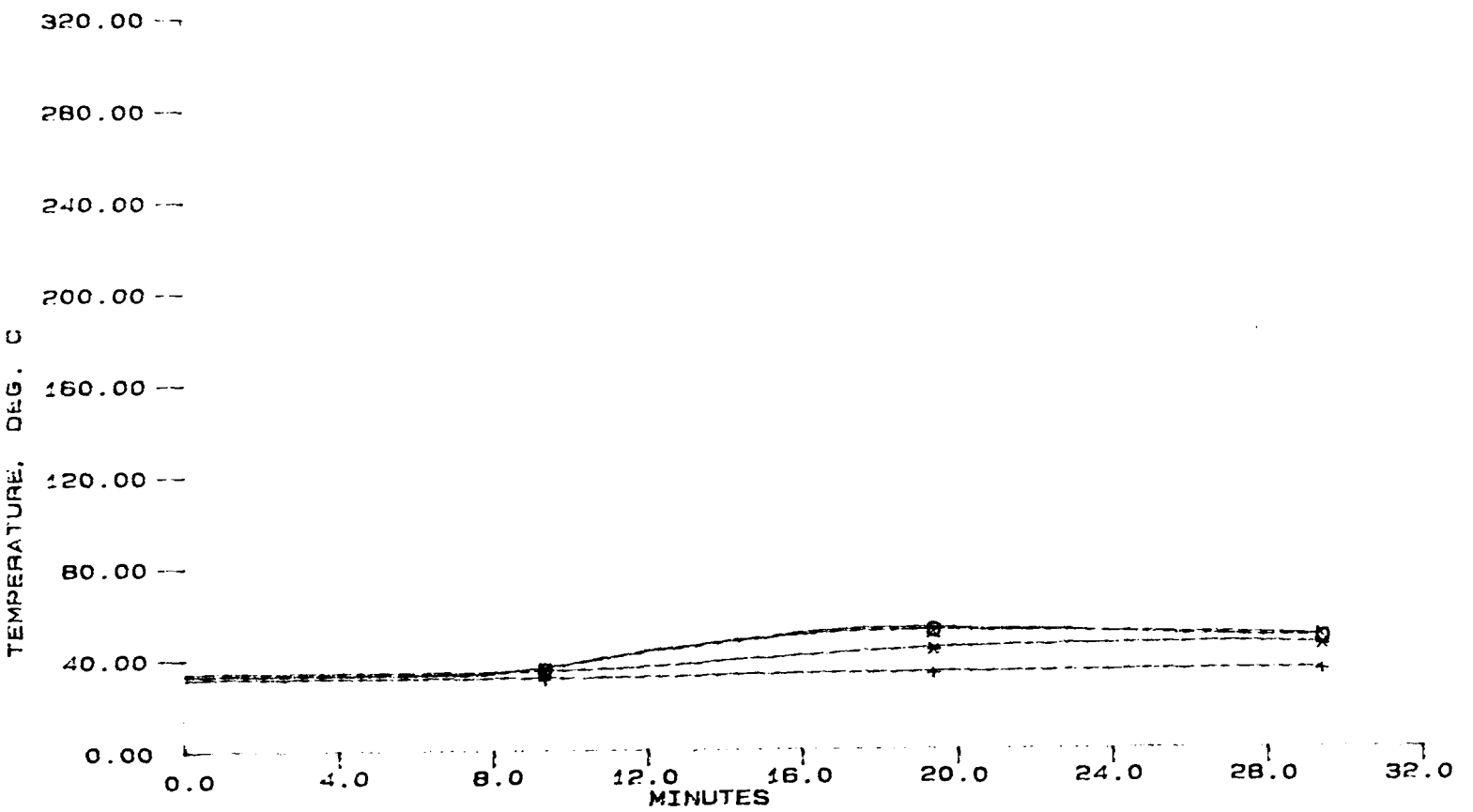


Fig. B-13 SMOKE CURTAIN TEST W-35 LEVEL 01 CH 84 85 86 87

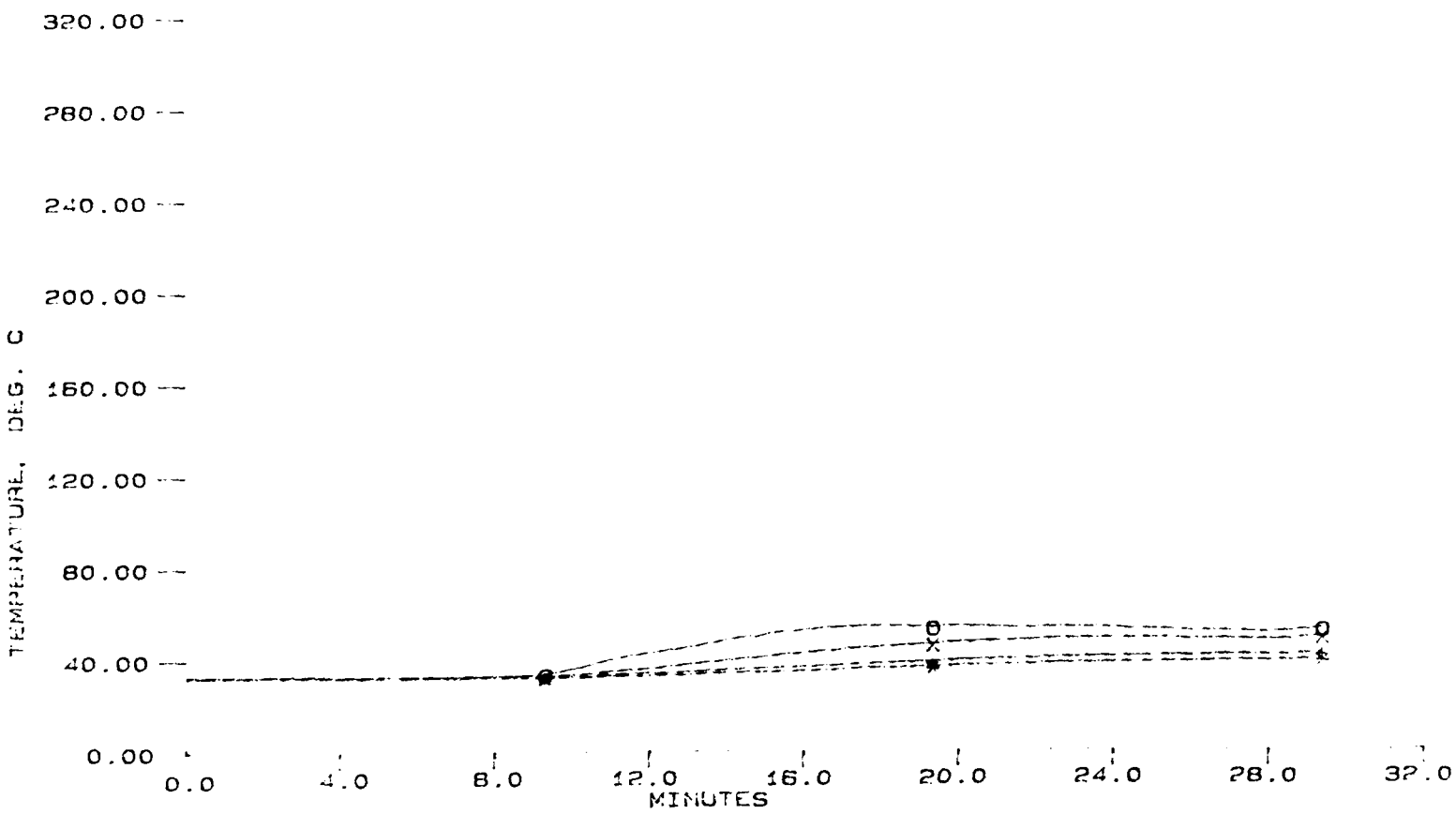


Fig. B-14 SMOKE CURTAIN TEST W-35 MAIN DECK CH 104 O, 105 X, 106 +, 107 *

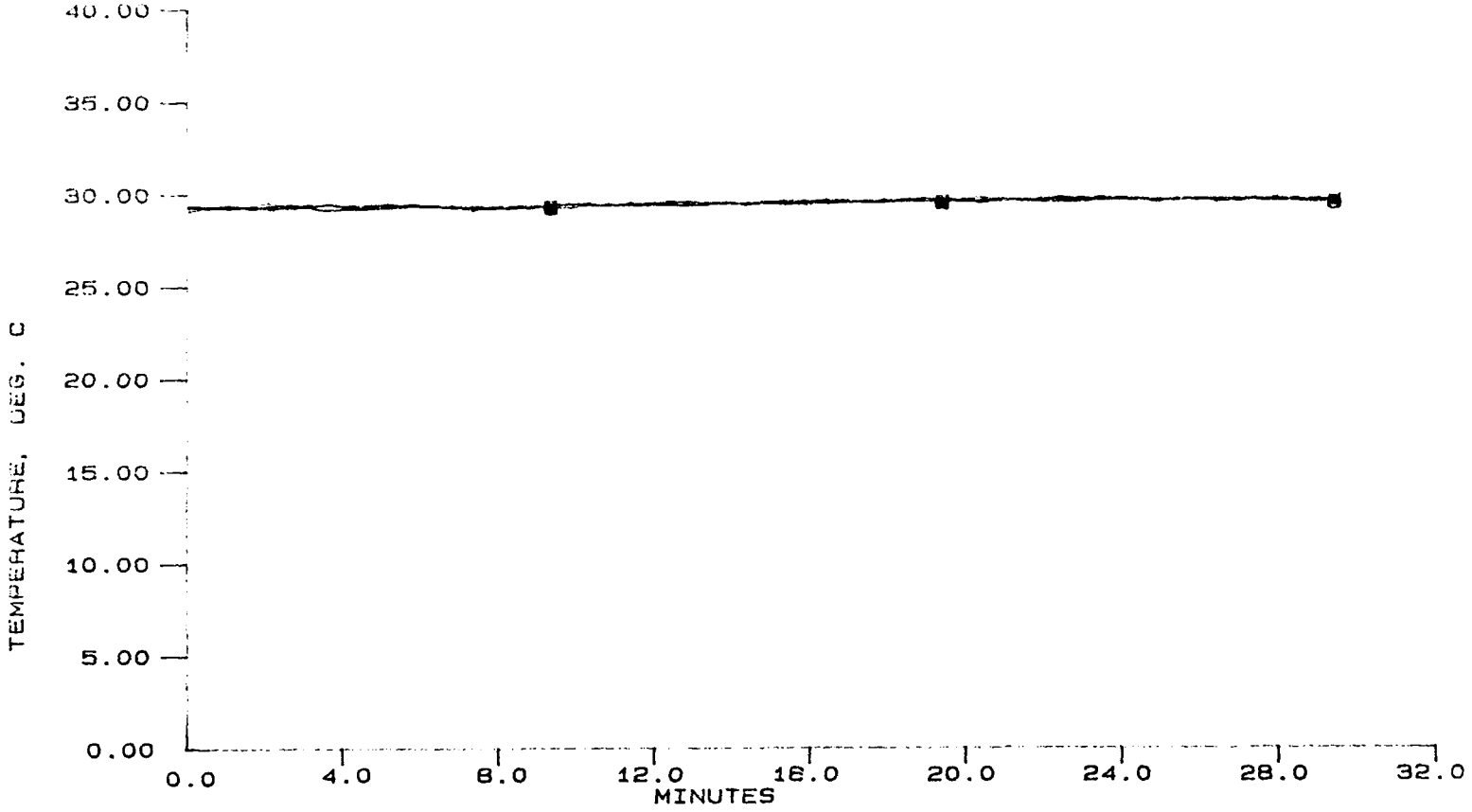


Fig. B-15 SMOKE CURTAIN TEST W [illegible] 100 O , 101 X , 102 + , 103 *

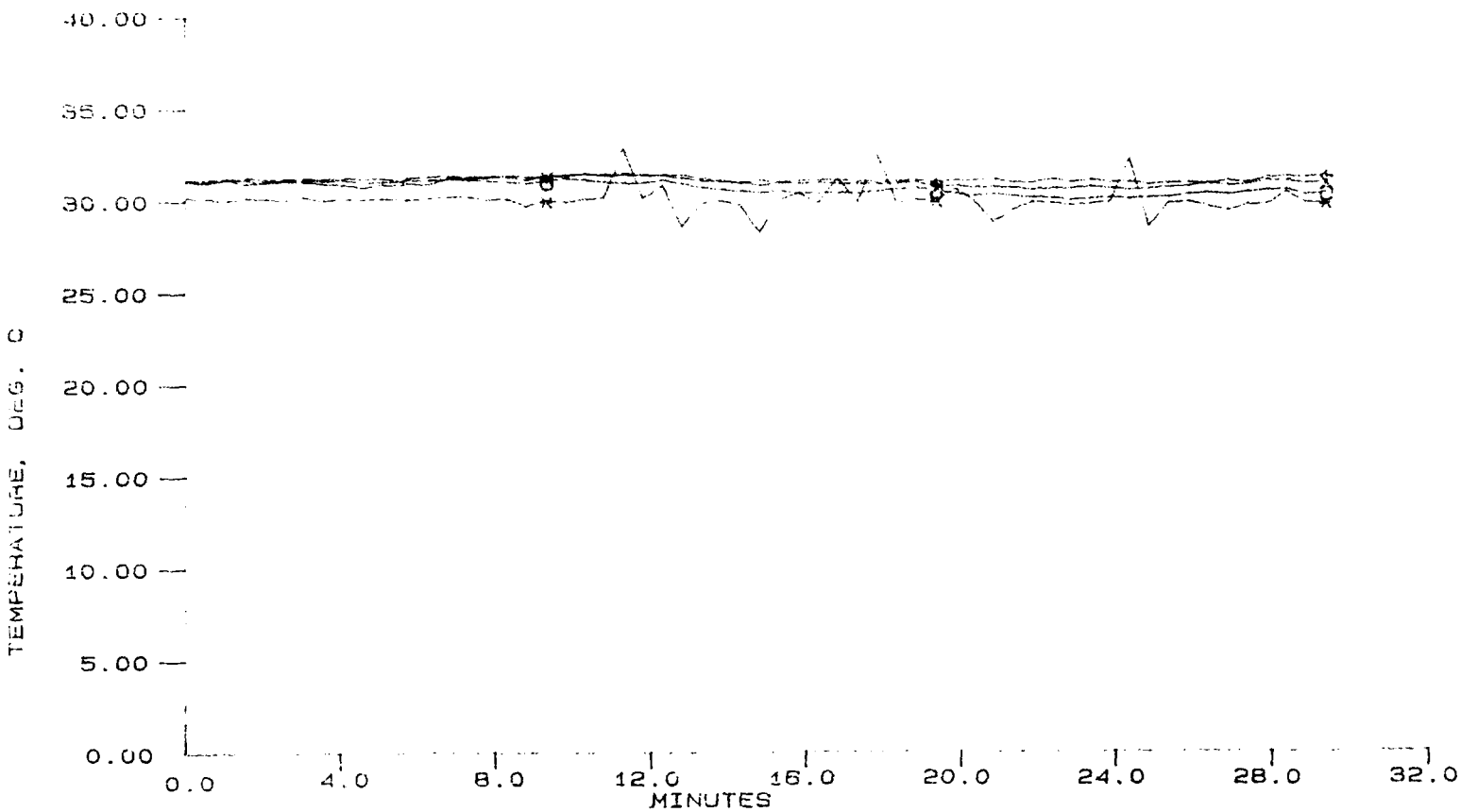


Fig. B-16 SMOKE CURTAIN TEST W-35 MAIN DECK CH 108 O, 109 X, 110 +, 111 *

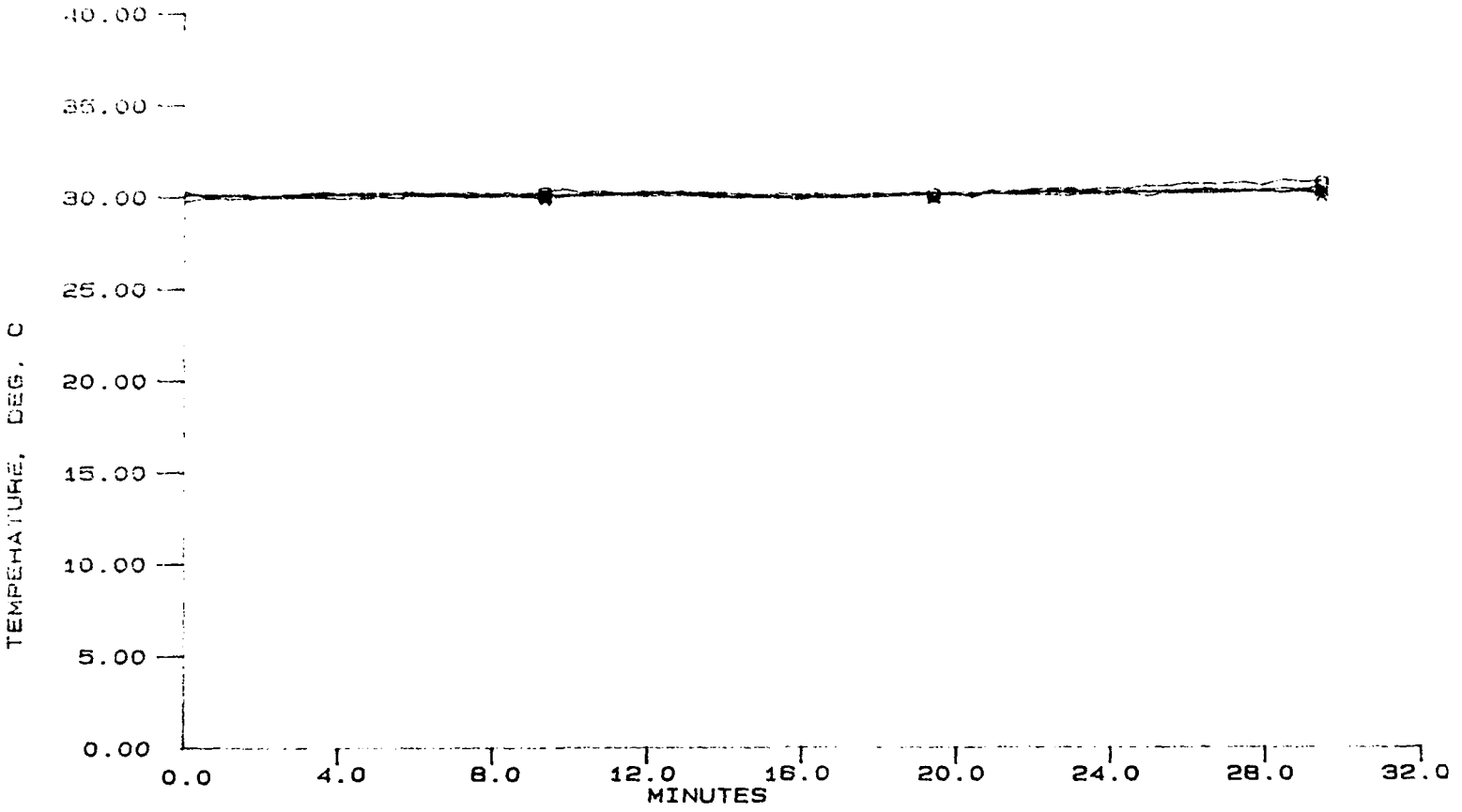


Fig. B-17 SMOKE CURTAIN TEST W-25 MAIL [illegible] O , [illegible] X

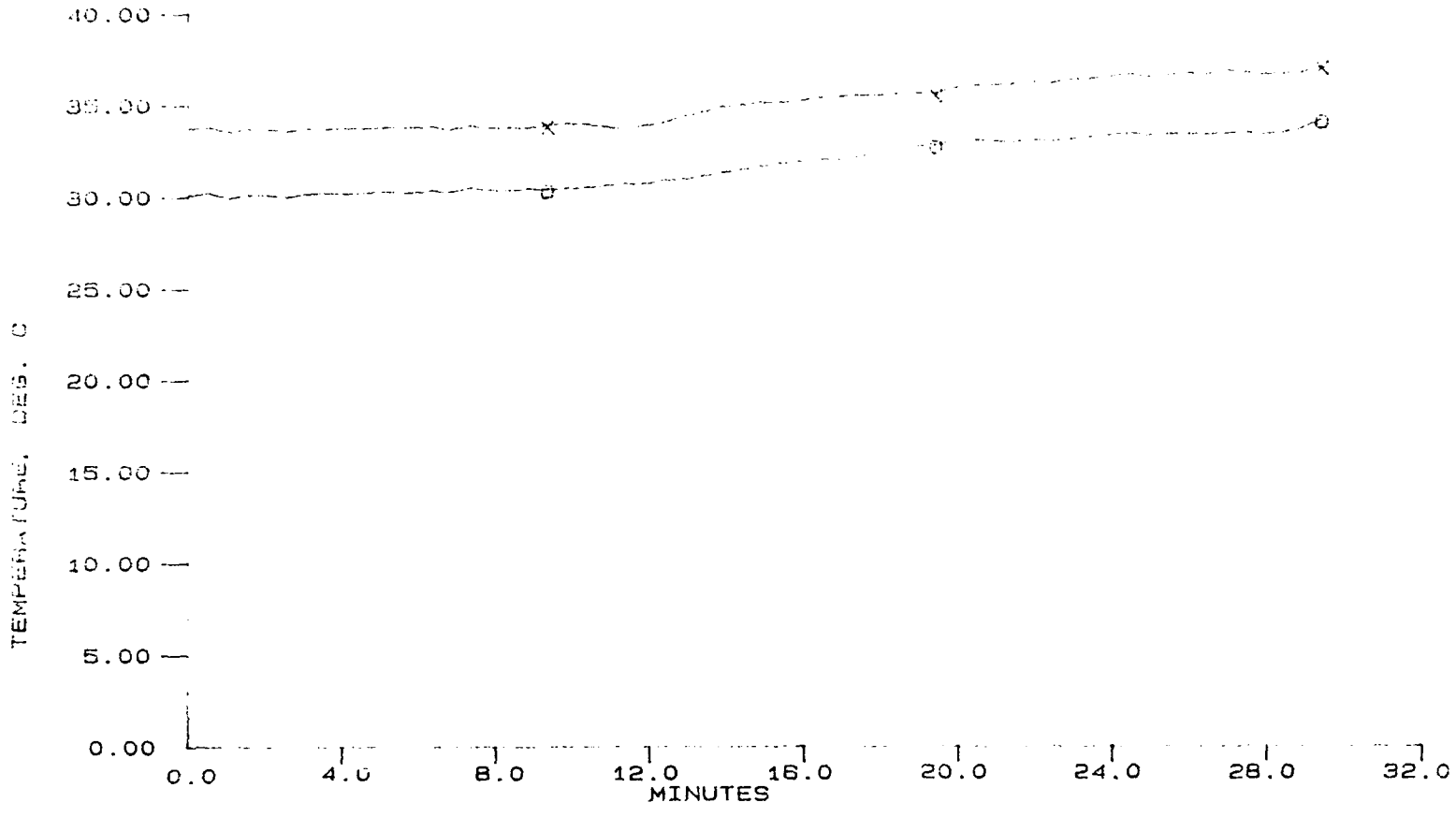


Fig. B-18 SMOKE CURTAIN TEST W-36 LEVEL 02 CH 116 O, 117 X, 118 +, 119 X

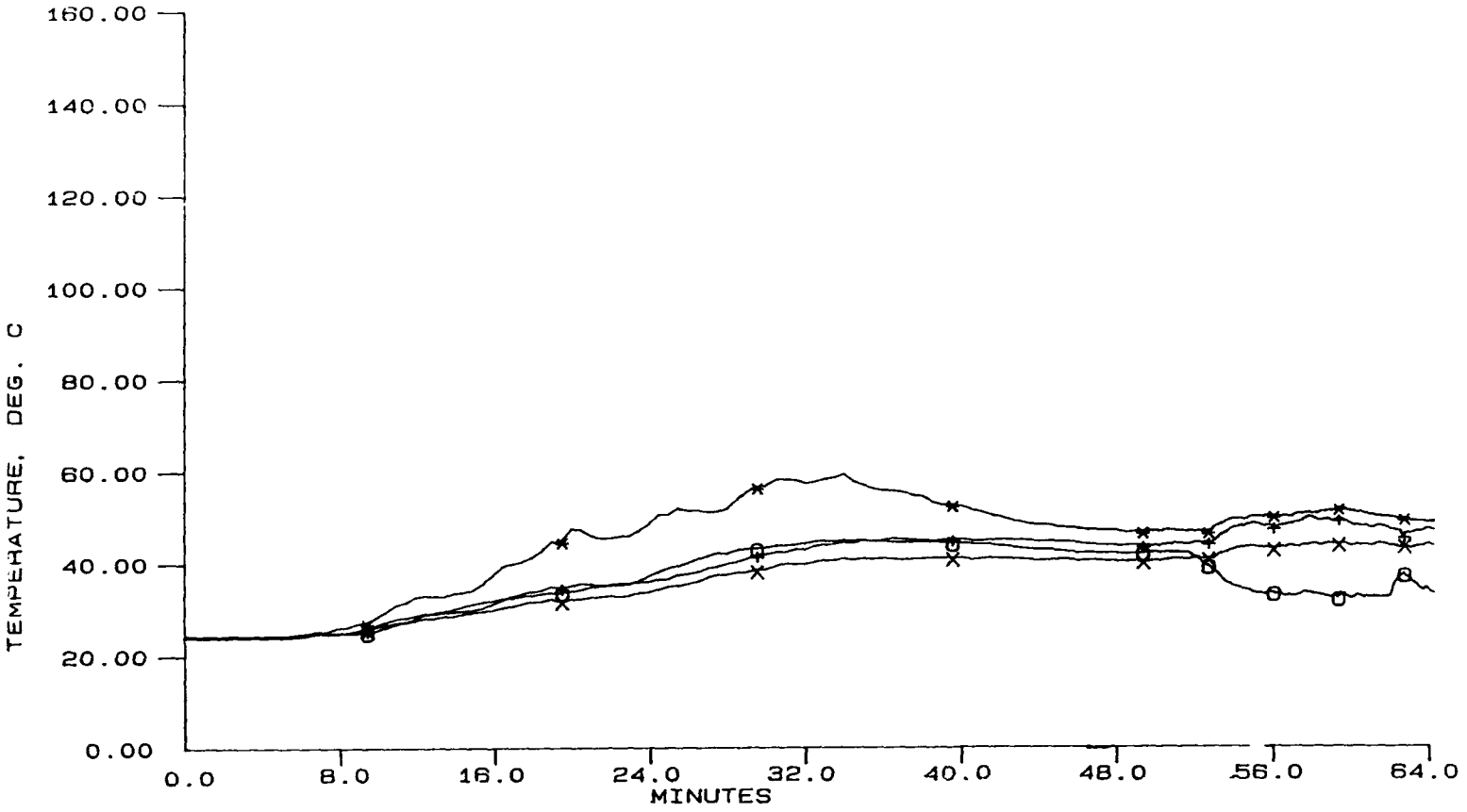


Fig. B-19 SMOKE CURTAIN TEST W-36 LEVEL 02 CH 56 ○ , 57 X , 58 + , 59 ✳

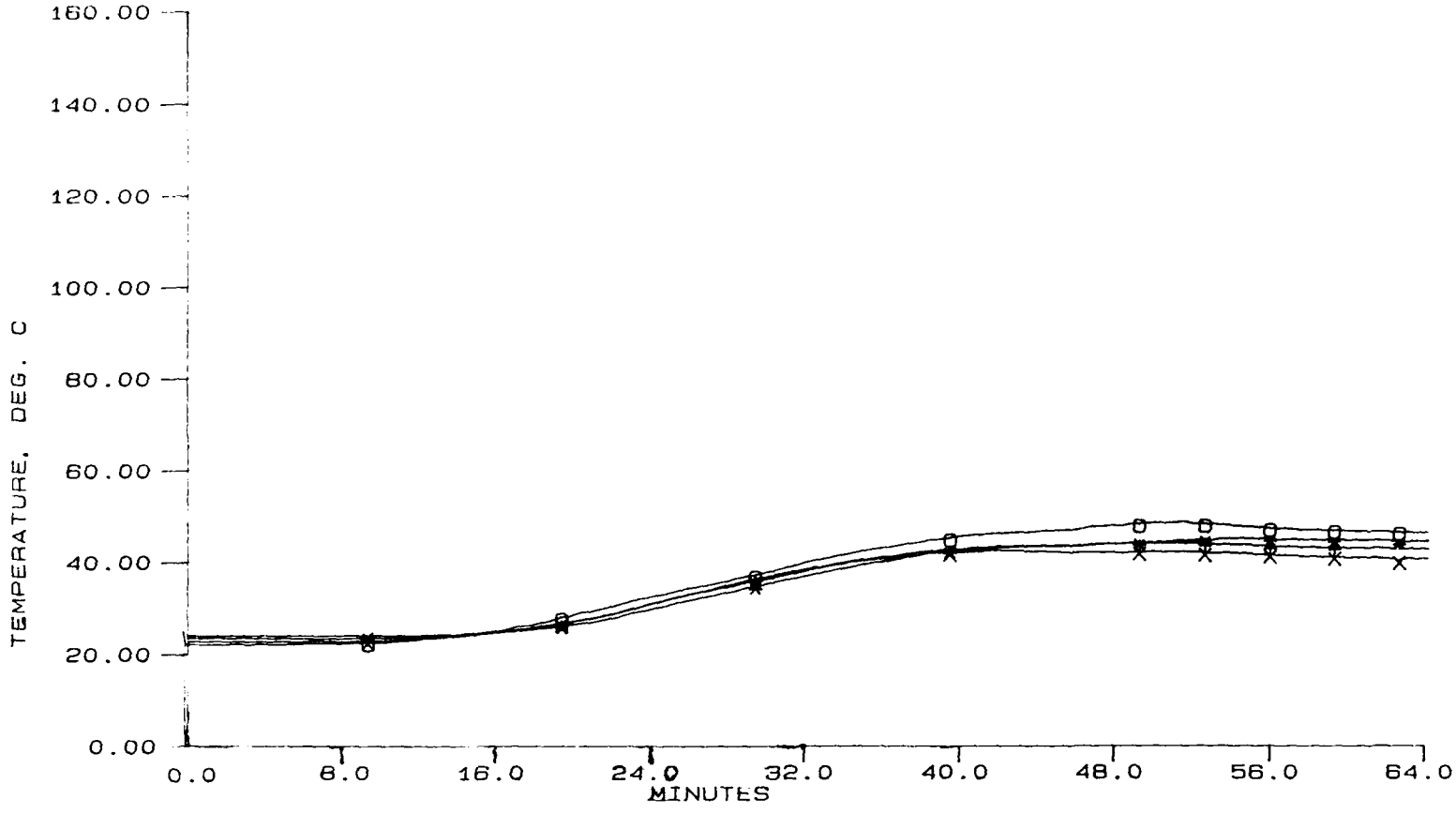


Fig. B-20 SMOKE CURTAIN TEST W-36 LEVEL 02 CH 52 ○ , 53 X , 54 + , 55 ✳

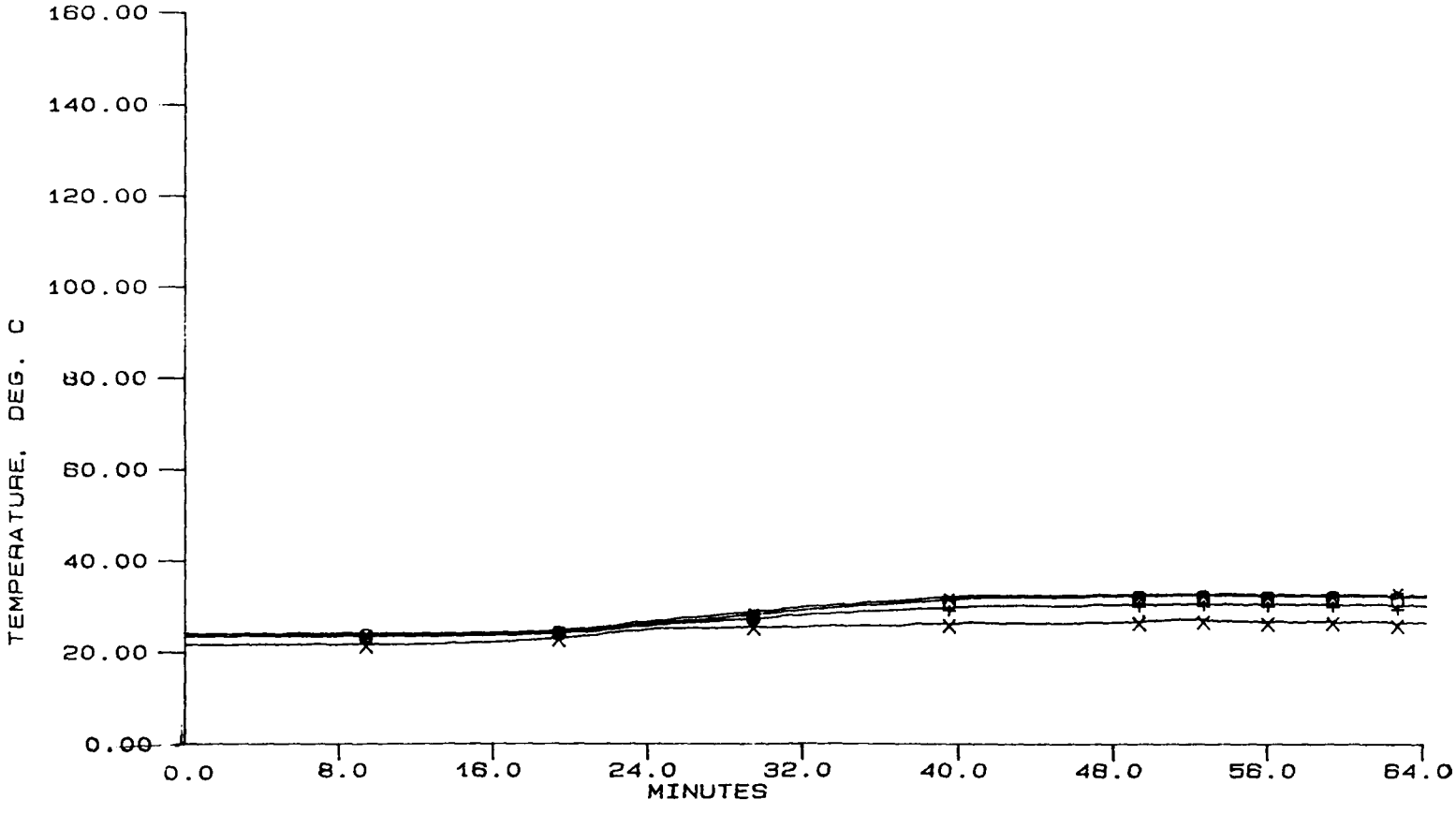


Fig. B-21 SMOKE CURTAIN TEST W-36 LEVEL 02 CH 48 ○ , 49 X , 50 + , 51 ✳

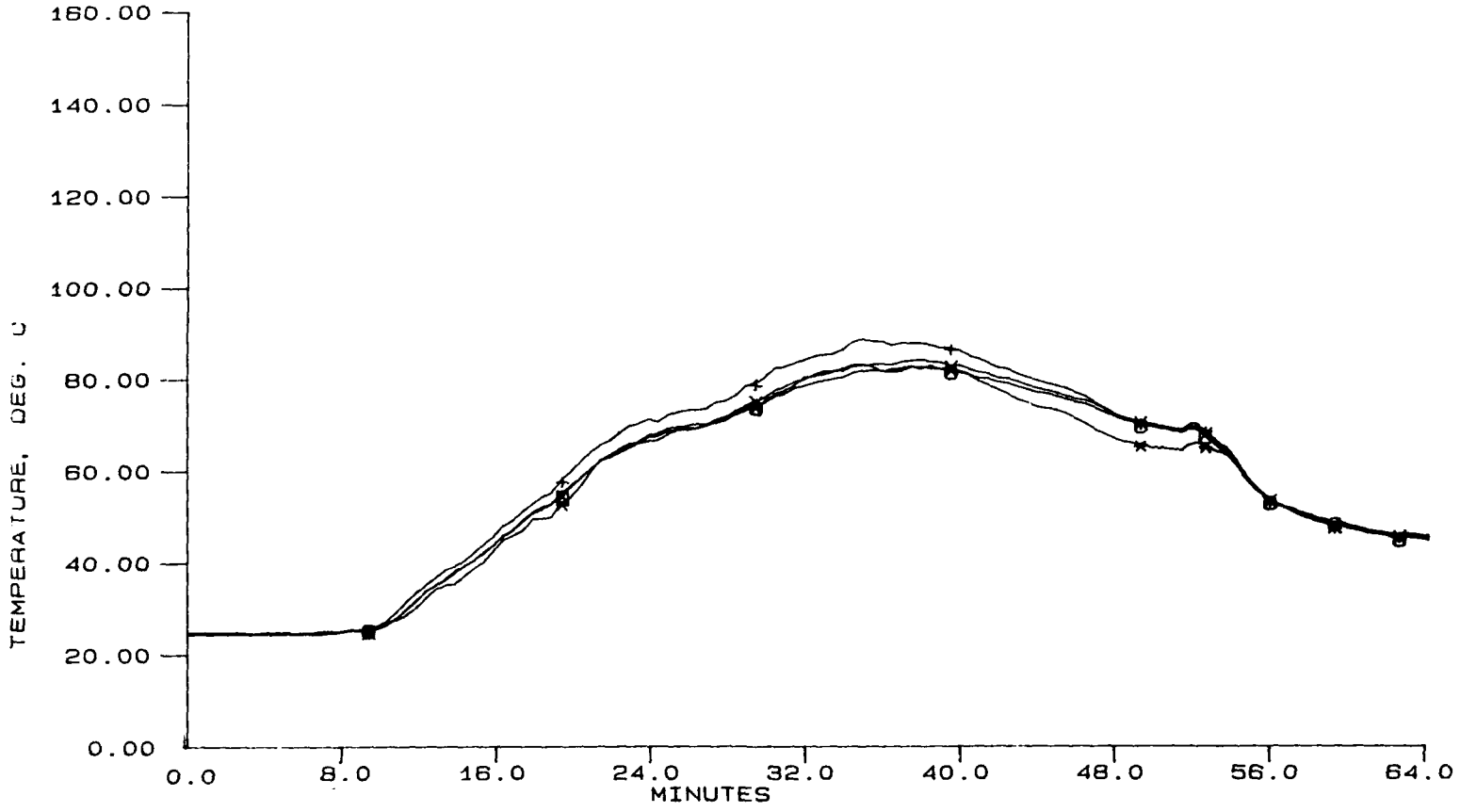


Fig. B-22 SMOKE CURTAIN TEST W-36 LEVEL 02 CH 44 ○ , 45 X , 46 + , 47 ✳

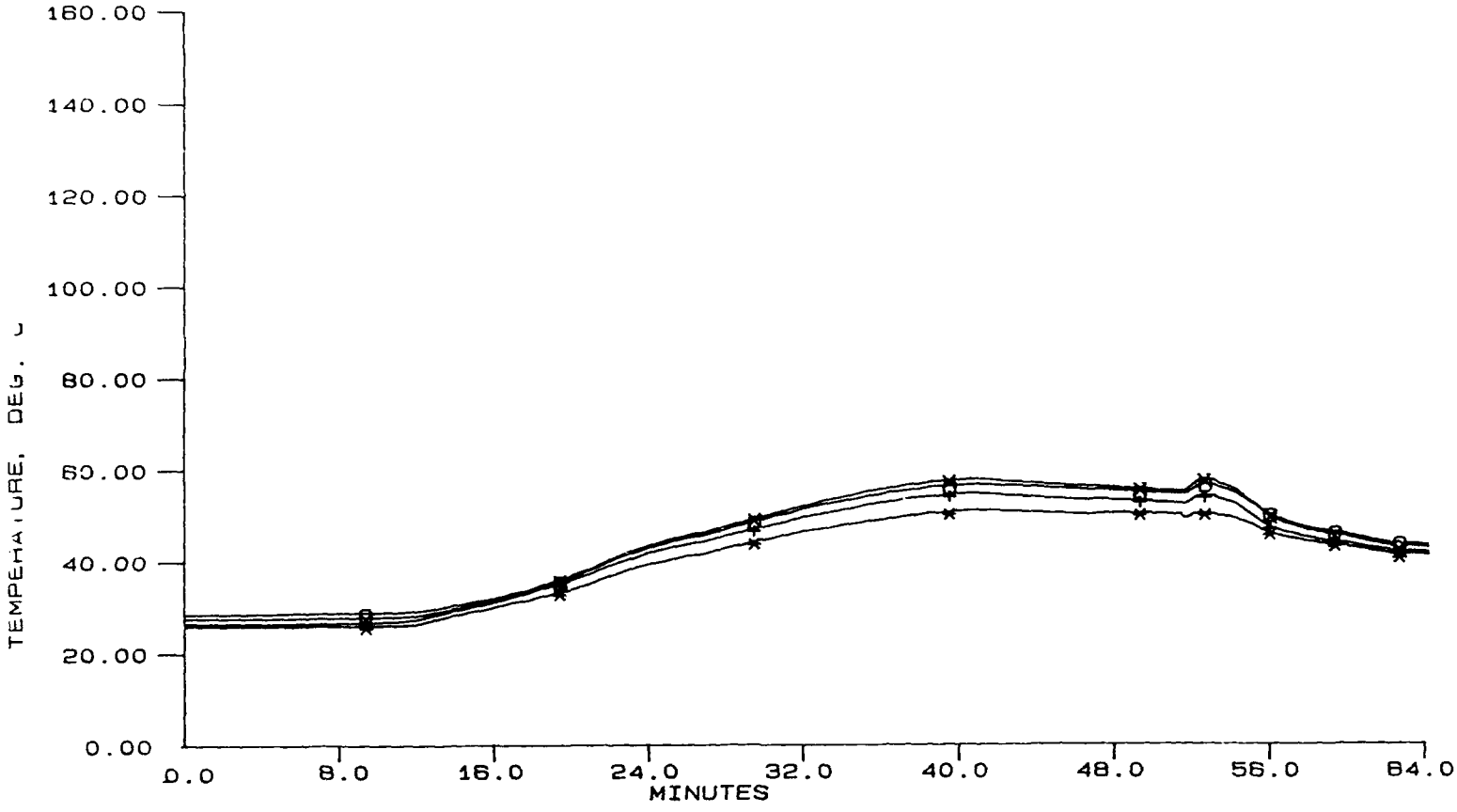


Fig. B-23 SMOKE CURTAIN TEST W-36 LEVEL 01 CH 72 ○ , 73 X , 74 + , 75 ✳

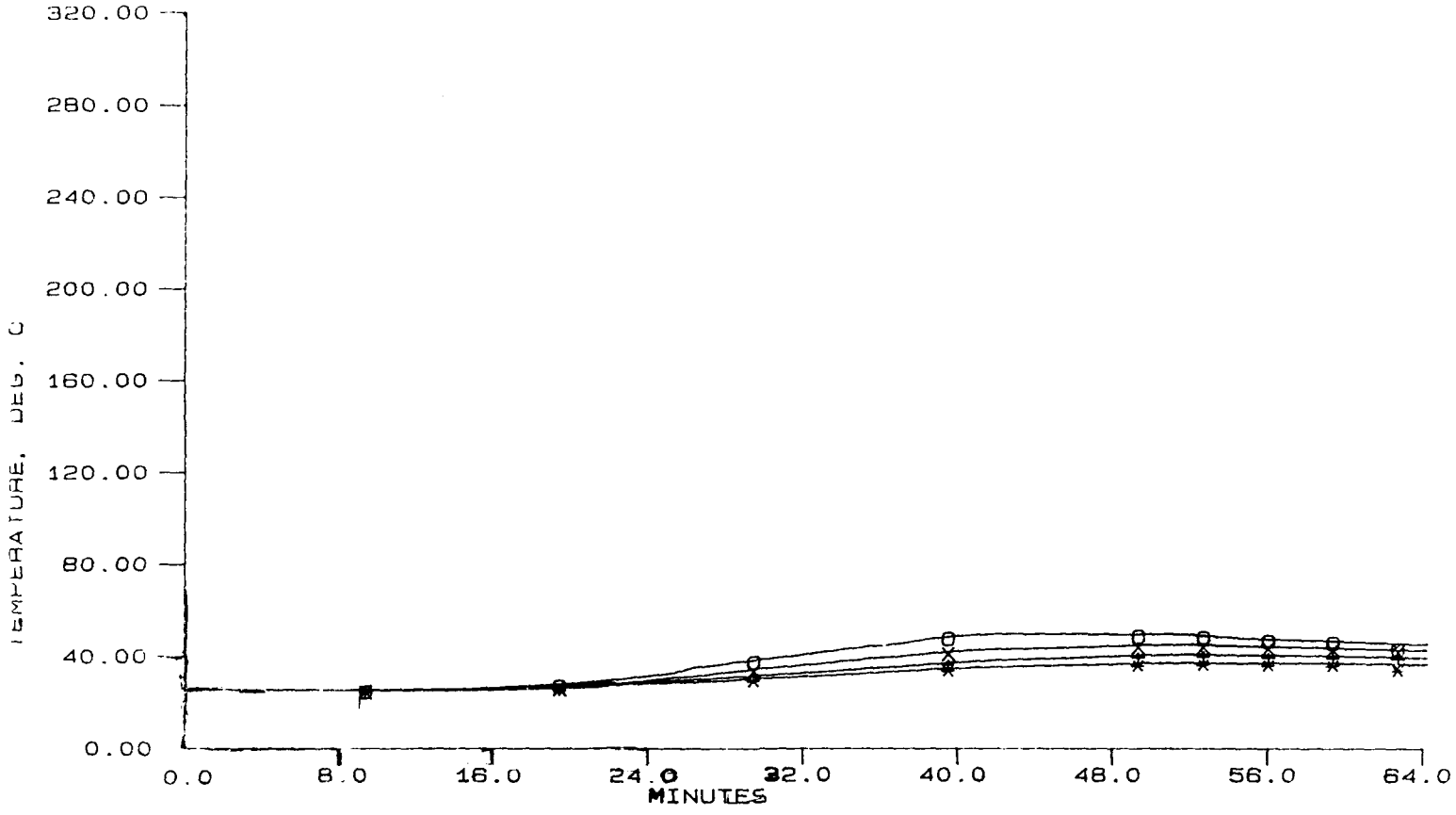


Fig. B-24 SMOKE CURTAIN TEST W-36 LEVEL 01 CH 64 ○ , 65 X , 66 + , 67 ✳

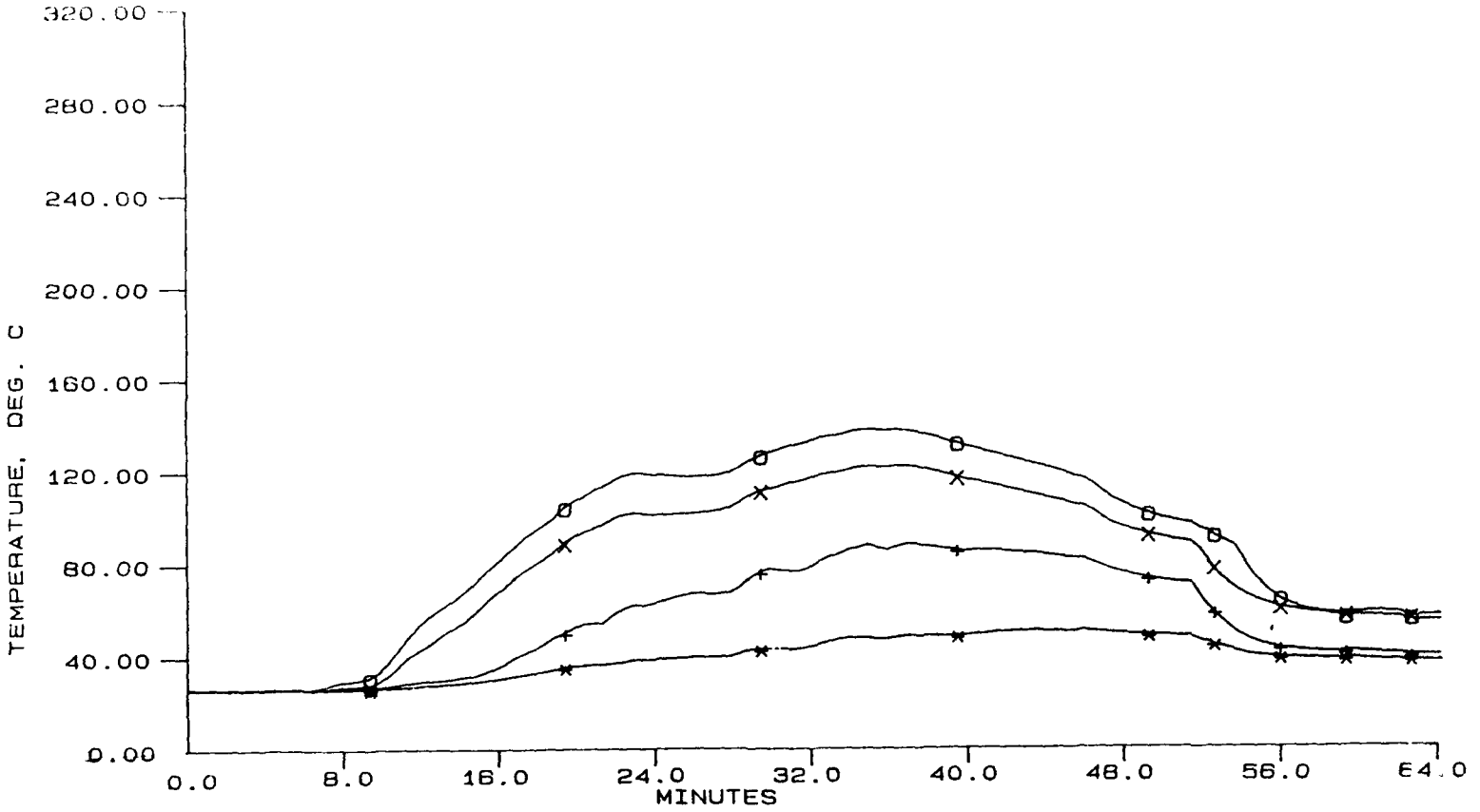


Fig. B-25 SMOKE CURTAIN TEST W-36 LEVEL 01 CH 60 ○ , 61 X , 62 + , 63 ✳

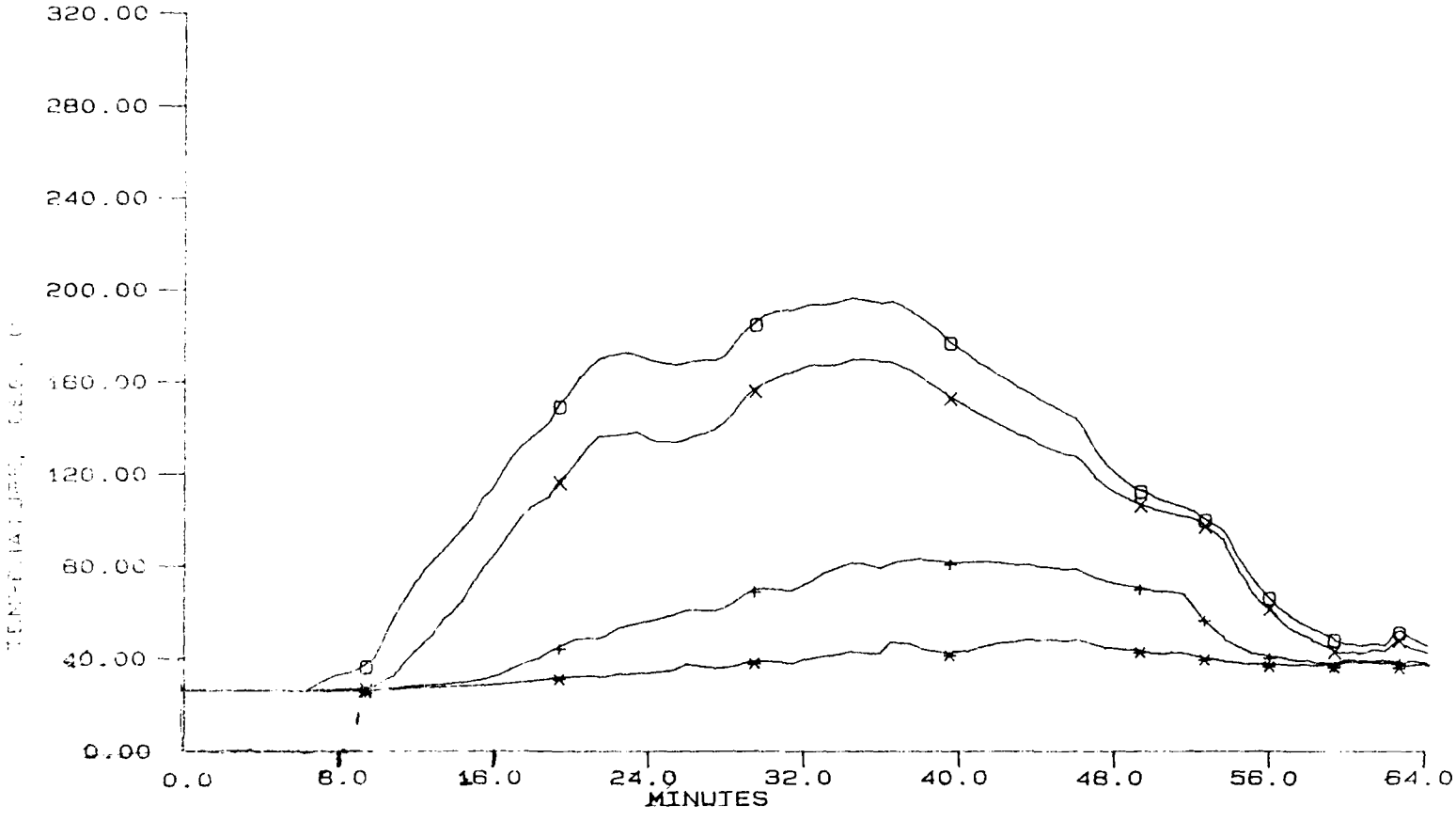


Fig. B-26 SMOKE CURTAIN TEST W-36 LEVEL 01 CH 68 O , 69 X , 70 + , 71 ✳

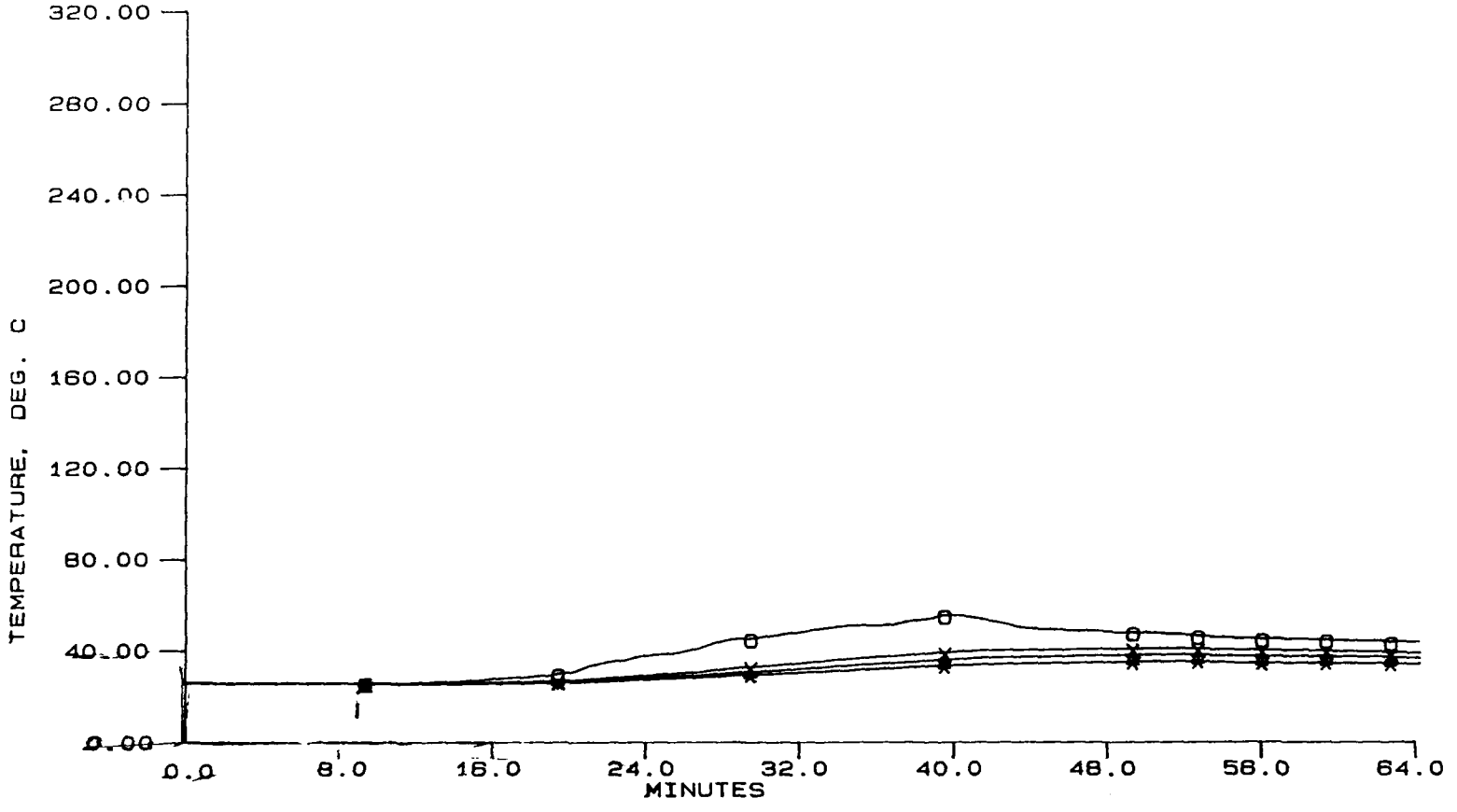


Fig. B-27 SMOKE CURTAIN TEST W-36 LEVEL 01 CH 112 O, 113 X, 114 +, 115 ✳

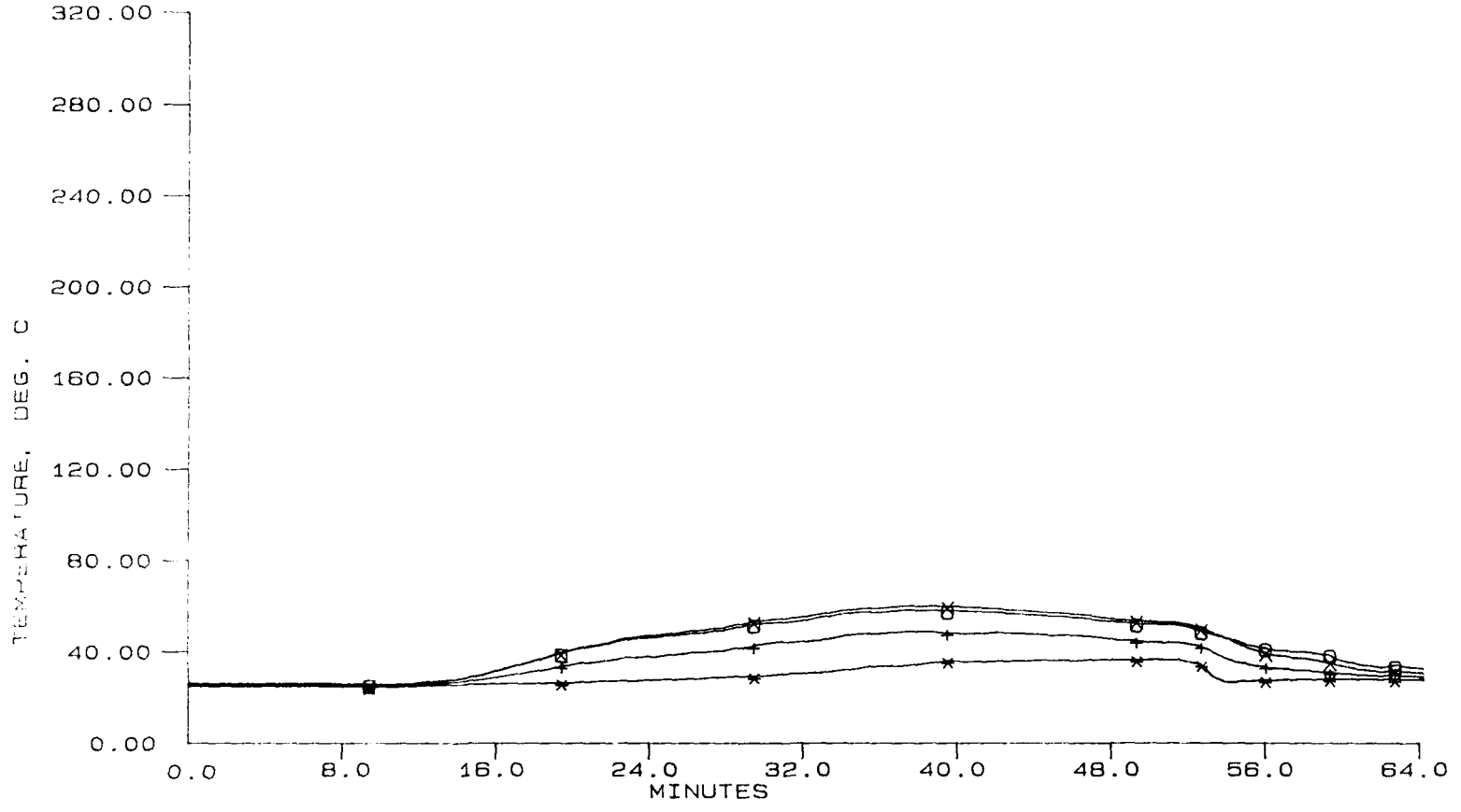


Fig. B-28 SMOKE CURTAIN TEST W-36 LEVEL 01 CH 76 ○ , 77 X , 78 + , 79 ✳

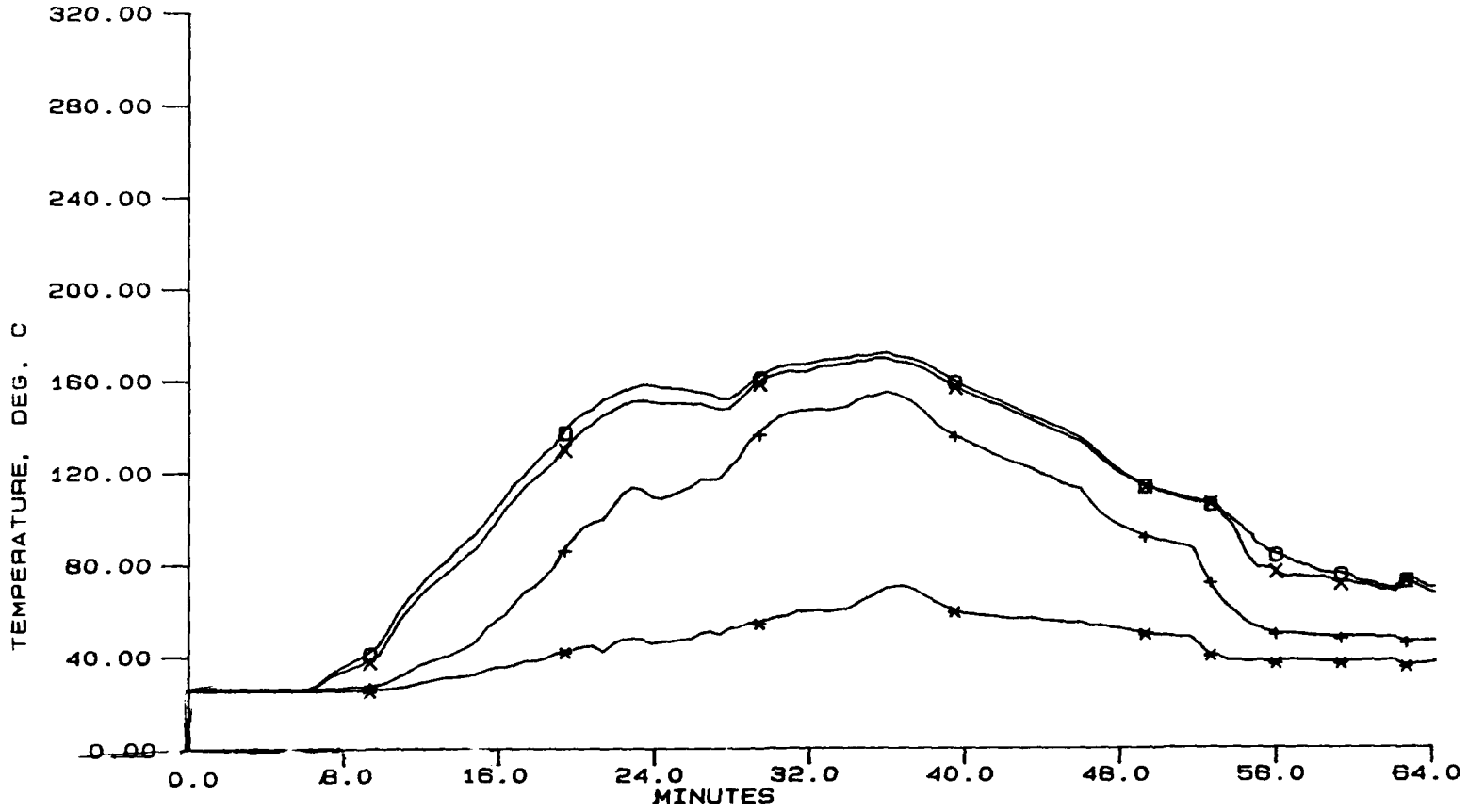


Fig. B-29 SMOKE CURTAIN TEST W-36 LEVEL 01 CH 80 O , 81 X , 82 + , 83 ✳

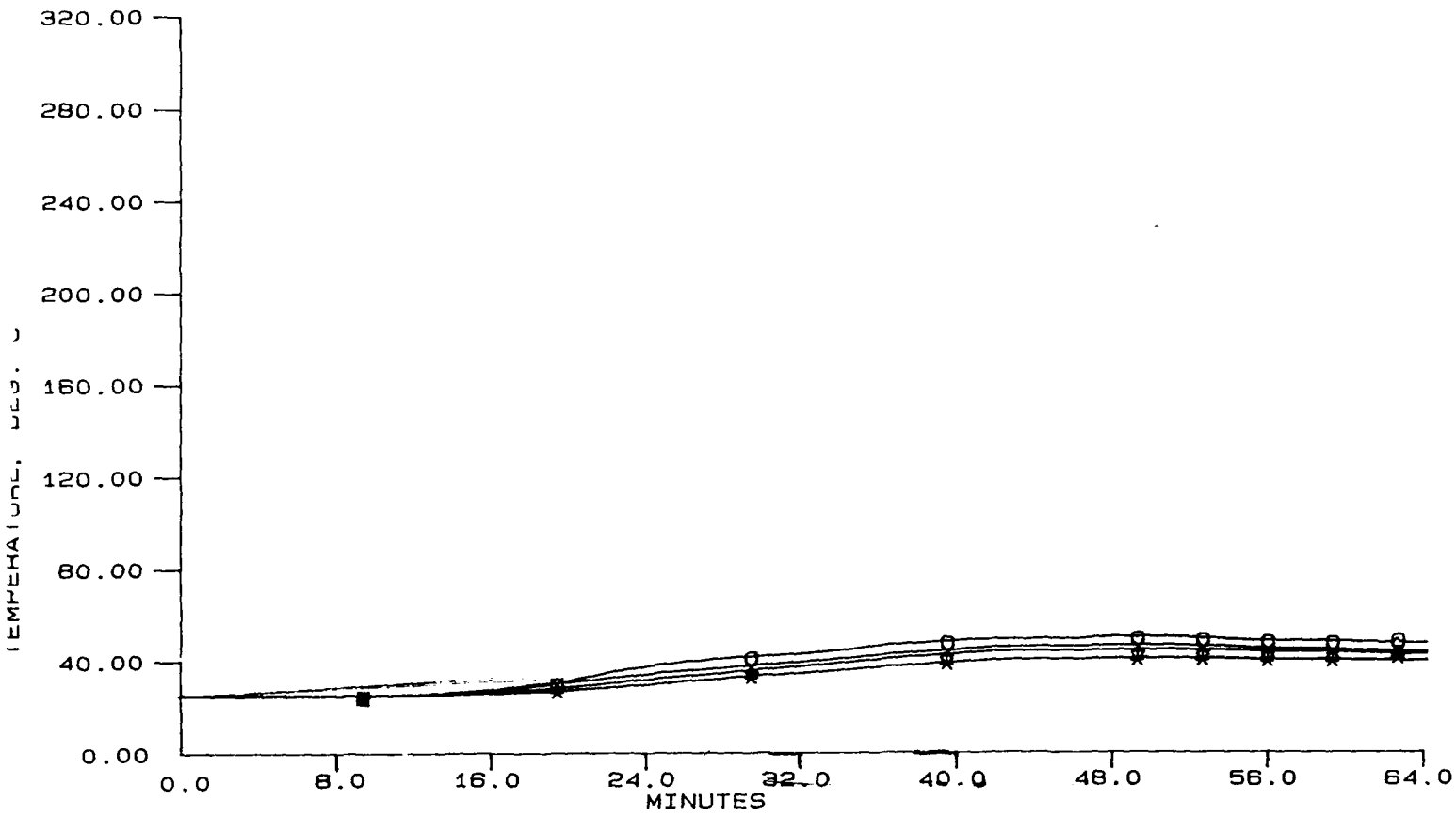


Fig. B-30 SMOKE CURTAIN TEST W-36 LEVEL 01 CH 84 ○ , 85 X , 86 + , 87 ✳

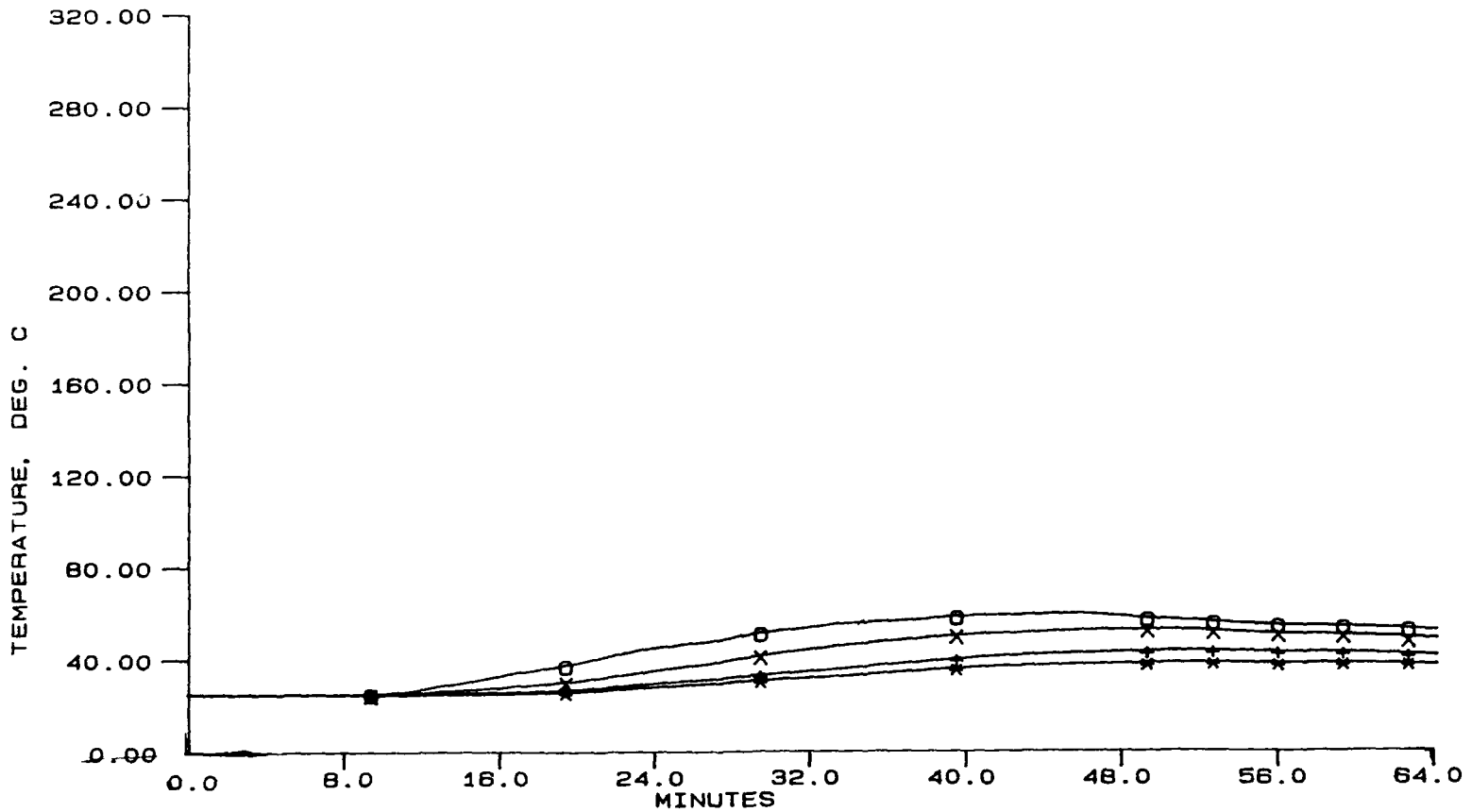


Fig. B-31 SMOKE CURTAIN TEST W-36 MAIN DECK CH 104 O, 105 X, 106 +, 107 ✳

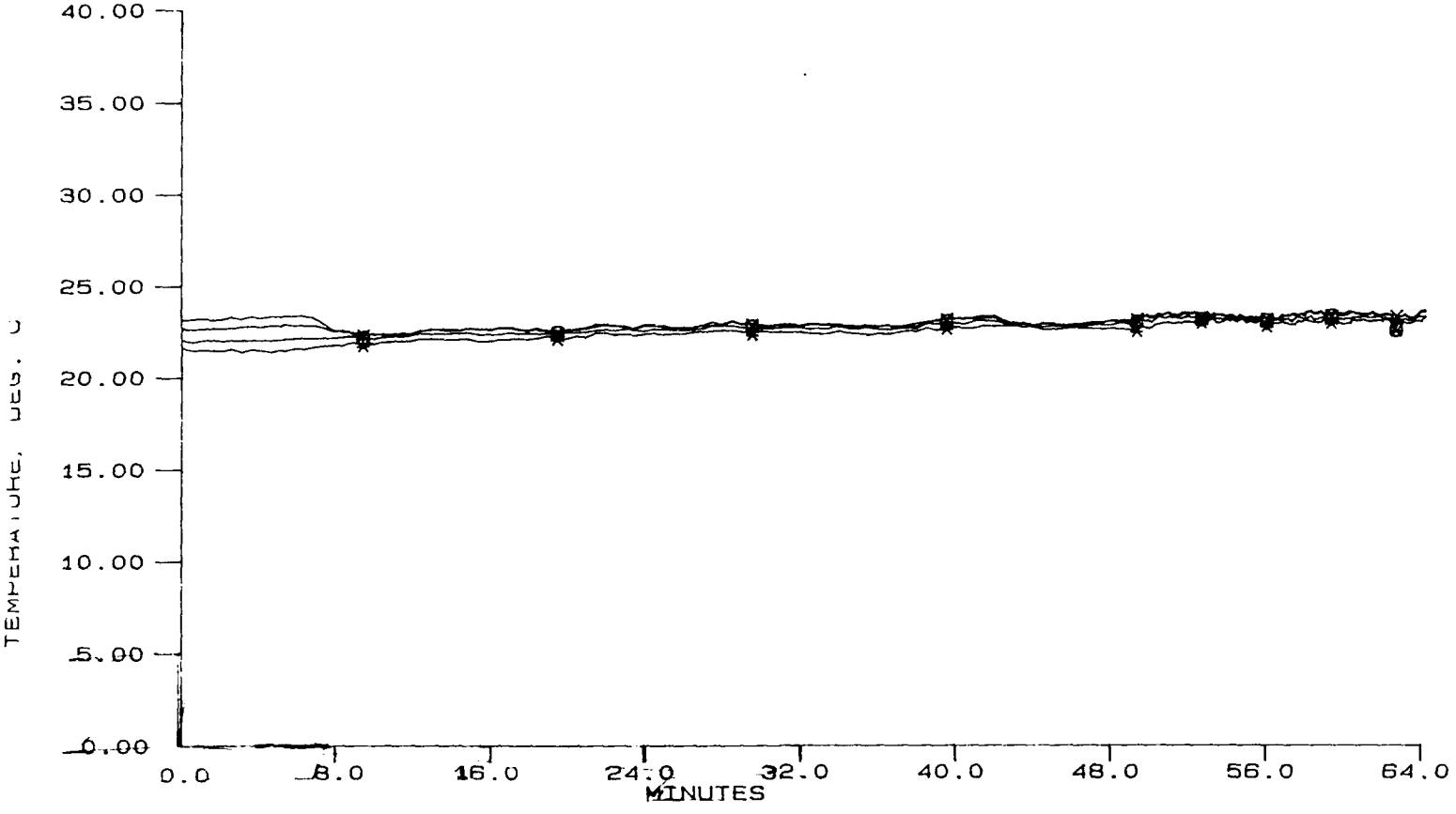


Fig. B-32 SMOKE CURTAIN TEST W-36 MAIN DECK CH 108 ○, 109 X, 110 +, 111 ✳

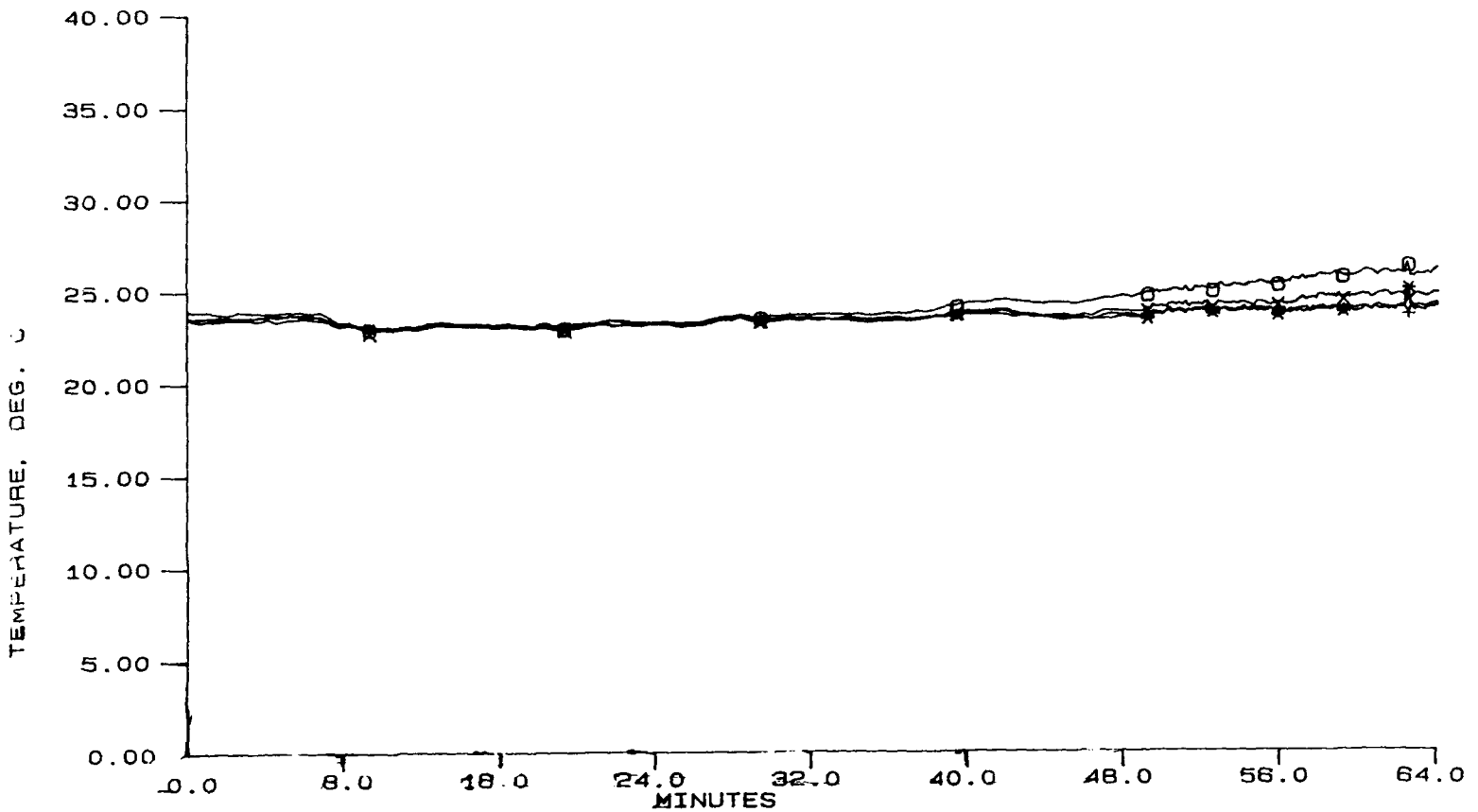


Fig. B-33 SMOKE CURTAIN TEST W-36 MAIN DECK CH 100 O, 101 X, 102 +, 103 *

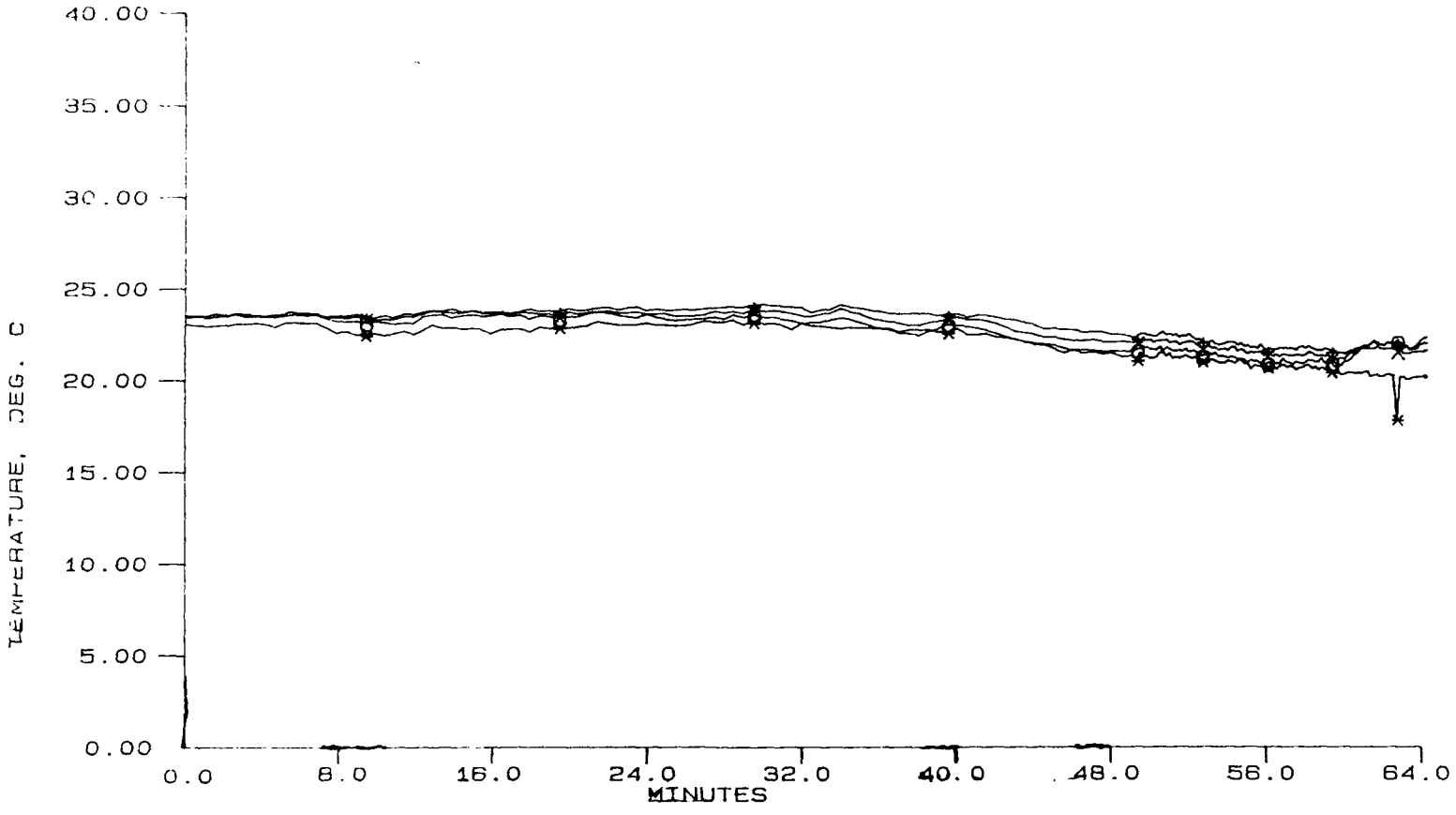
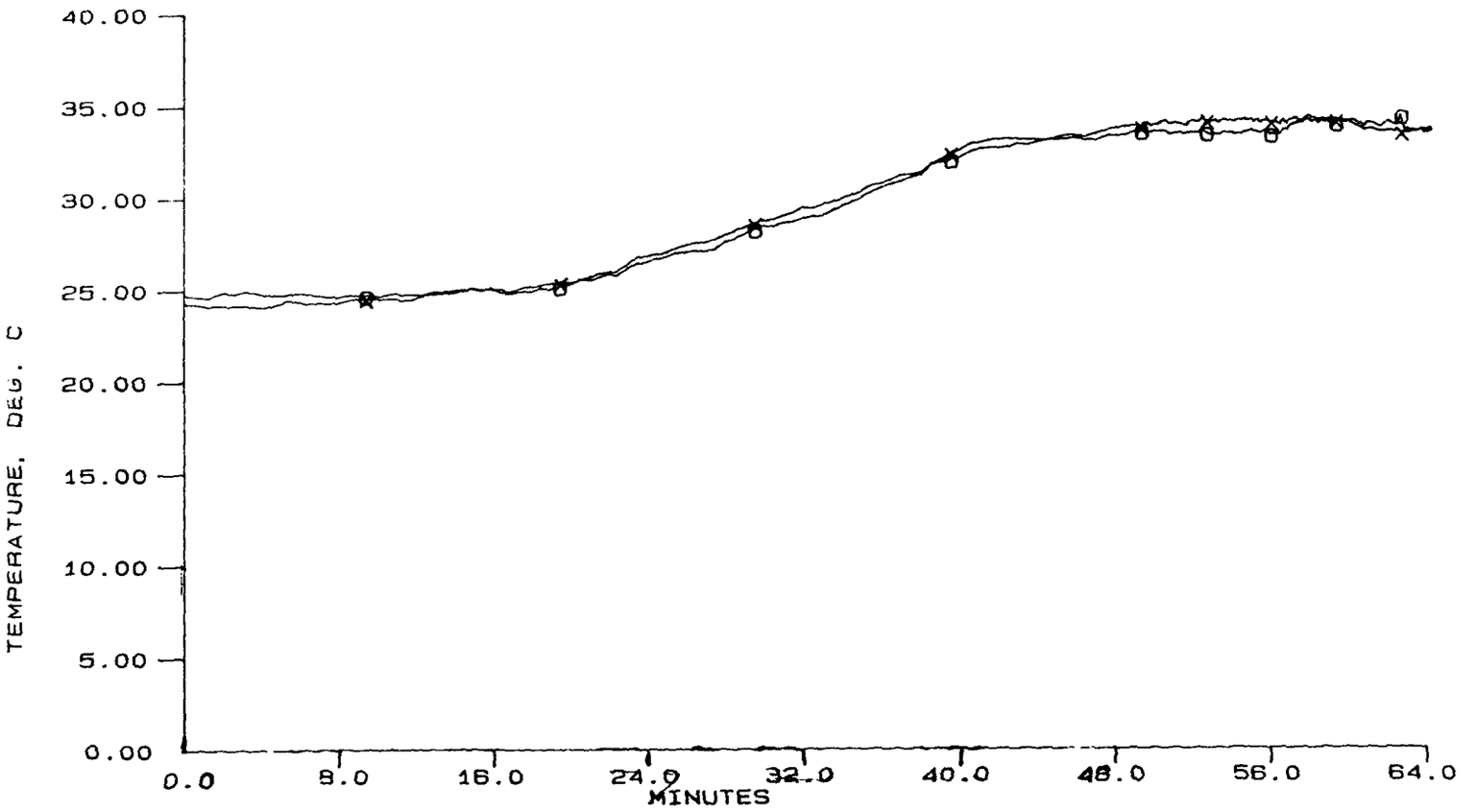


Fig. B-34 SMOKE CURTAIN TEST W-38 MAIN DECK CH 94 ○ , 98 X



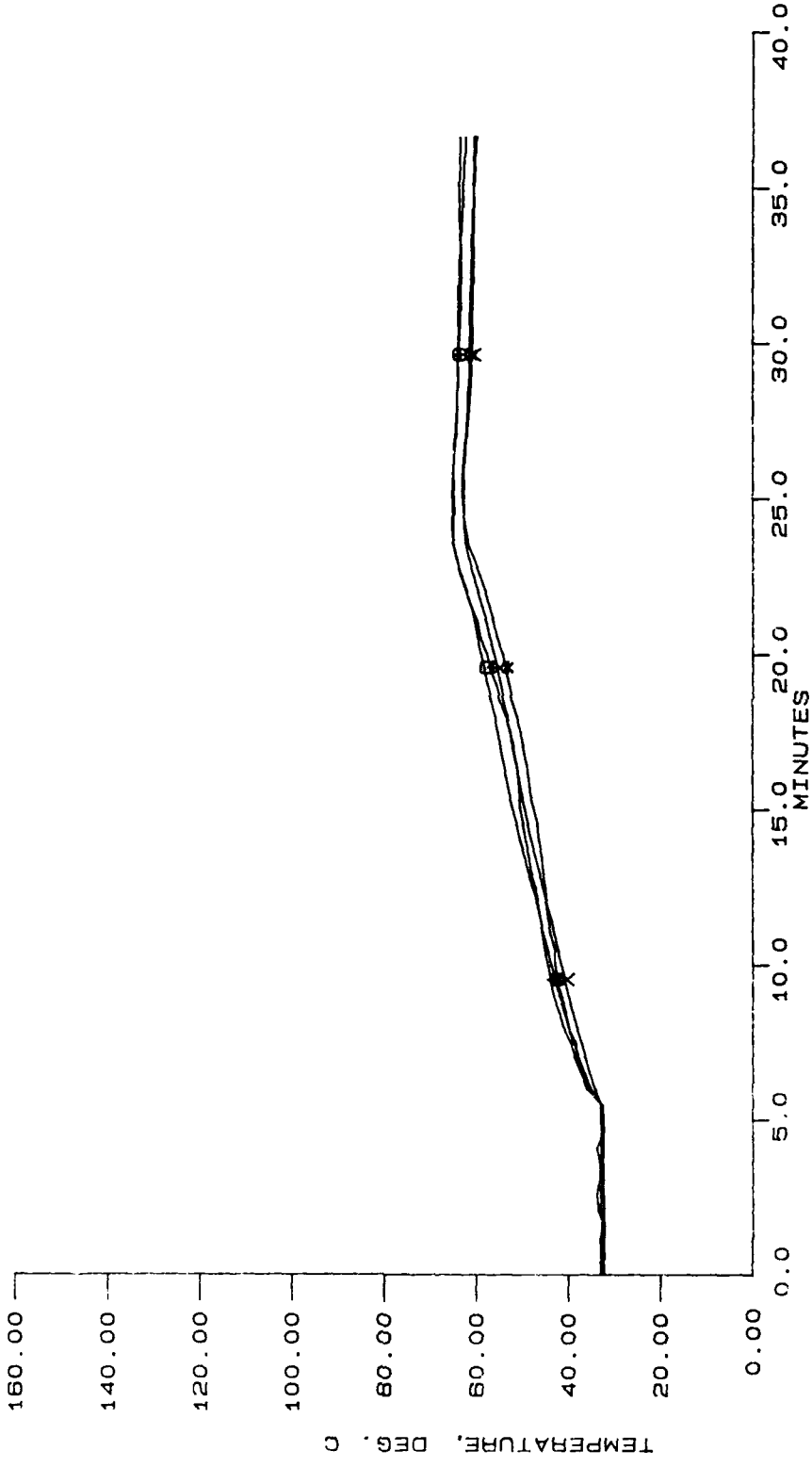

SMOKE CURTAIN TEST W-37 LEVEL 02 CH 116 ○, 117 X, 118 +, 119 ✳
TEMPERATURE, DEG. C
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
MINUTES

Fig. B-35

Fig. B-36 SMOKE CURTAIN TEST W-37 LEVEL 02 CH 56 O, 57 X, 58 +, 59 X

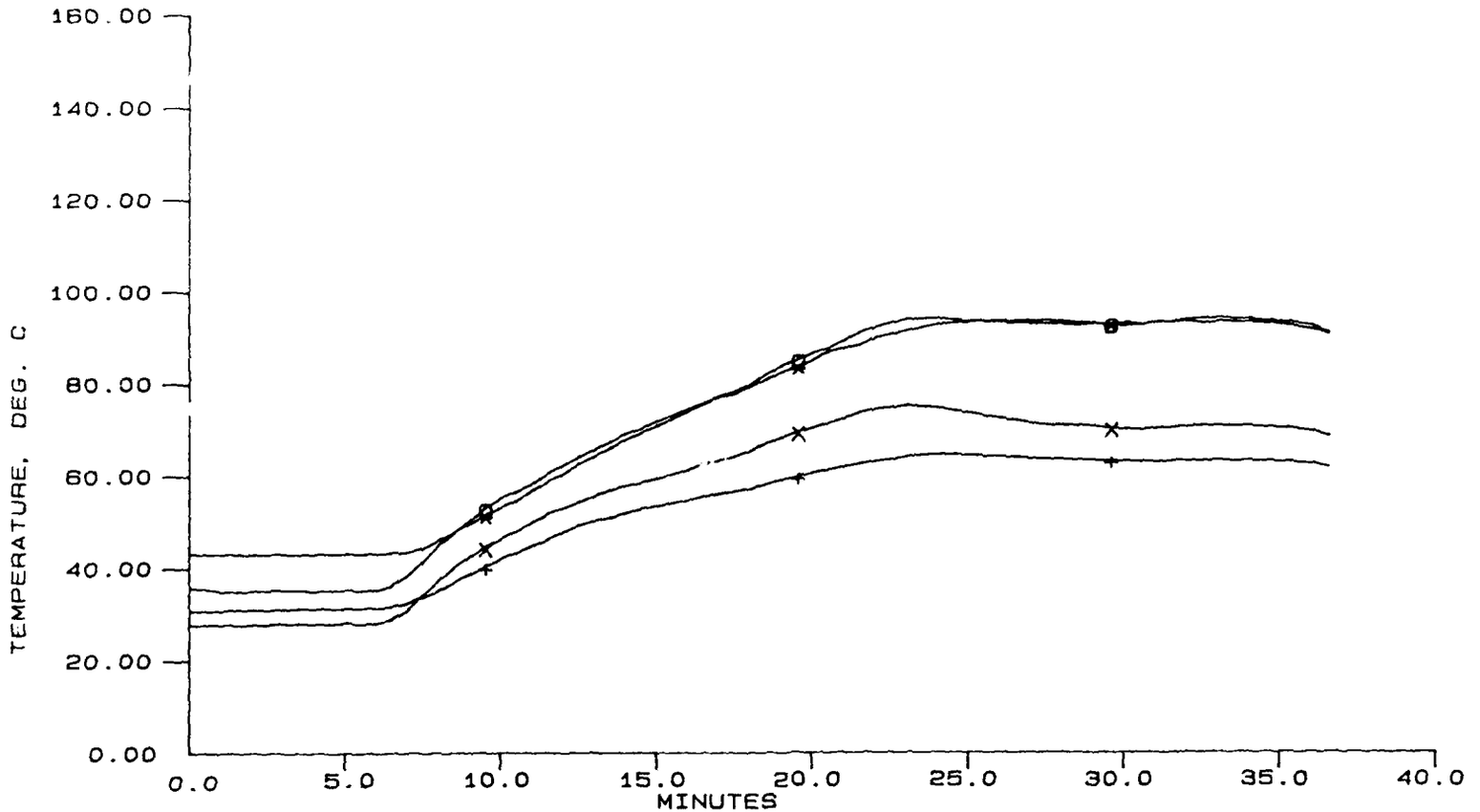


Fig. B-37 SMOKE CURTAIN TEST W-37 LEVEL 02 CH 52 ○, 53 X, 54 +, 55 X

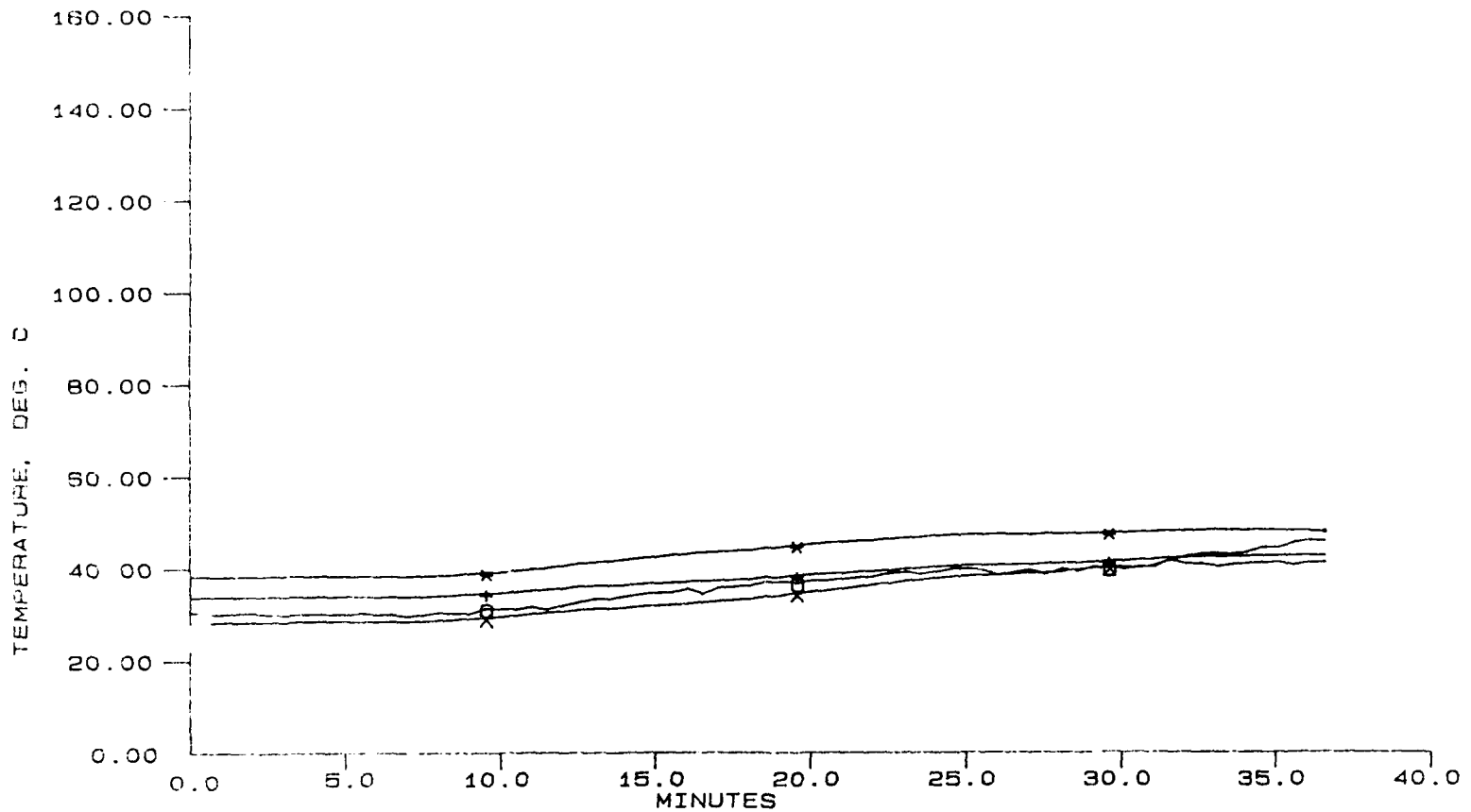


Fig. B-38 SMOKE CURTAIN TEST W-37 LEVEL 02 CH 48 ○, 49 ×, 50 +, 51 ✳

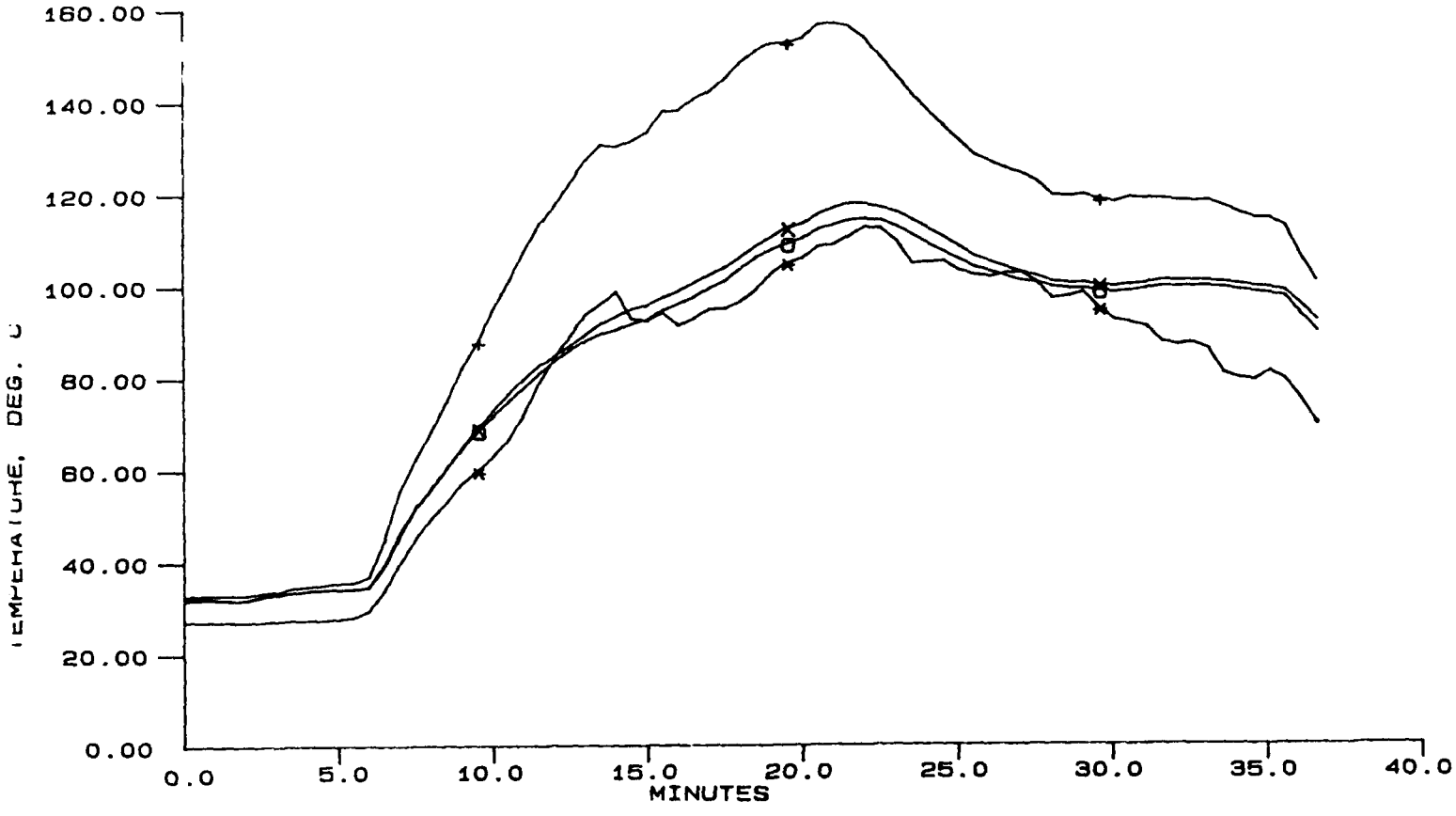


Fig. B-39 SMOKE CURTAIN TEST W-37 LEVEL 02 CH 44 ○, 45 X, 46 +, 47 ✳

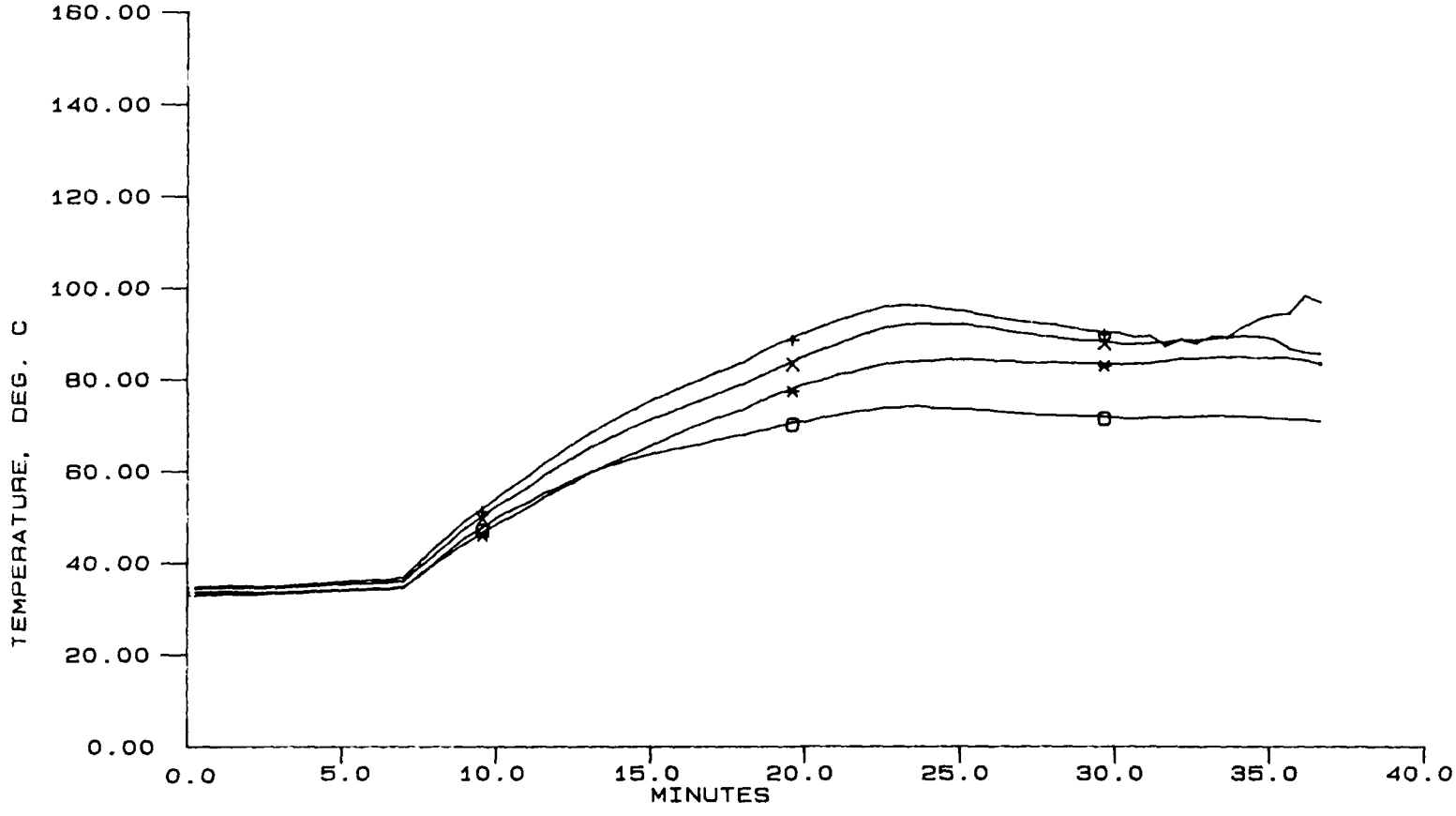


Fig. B-40 SMOKE CURTAIN TEST W-37 LEVEL 01 CH 72 ○, 73 X, 74 +, 75 ✳

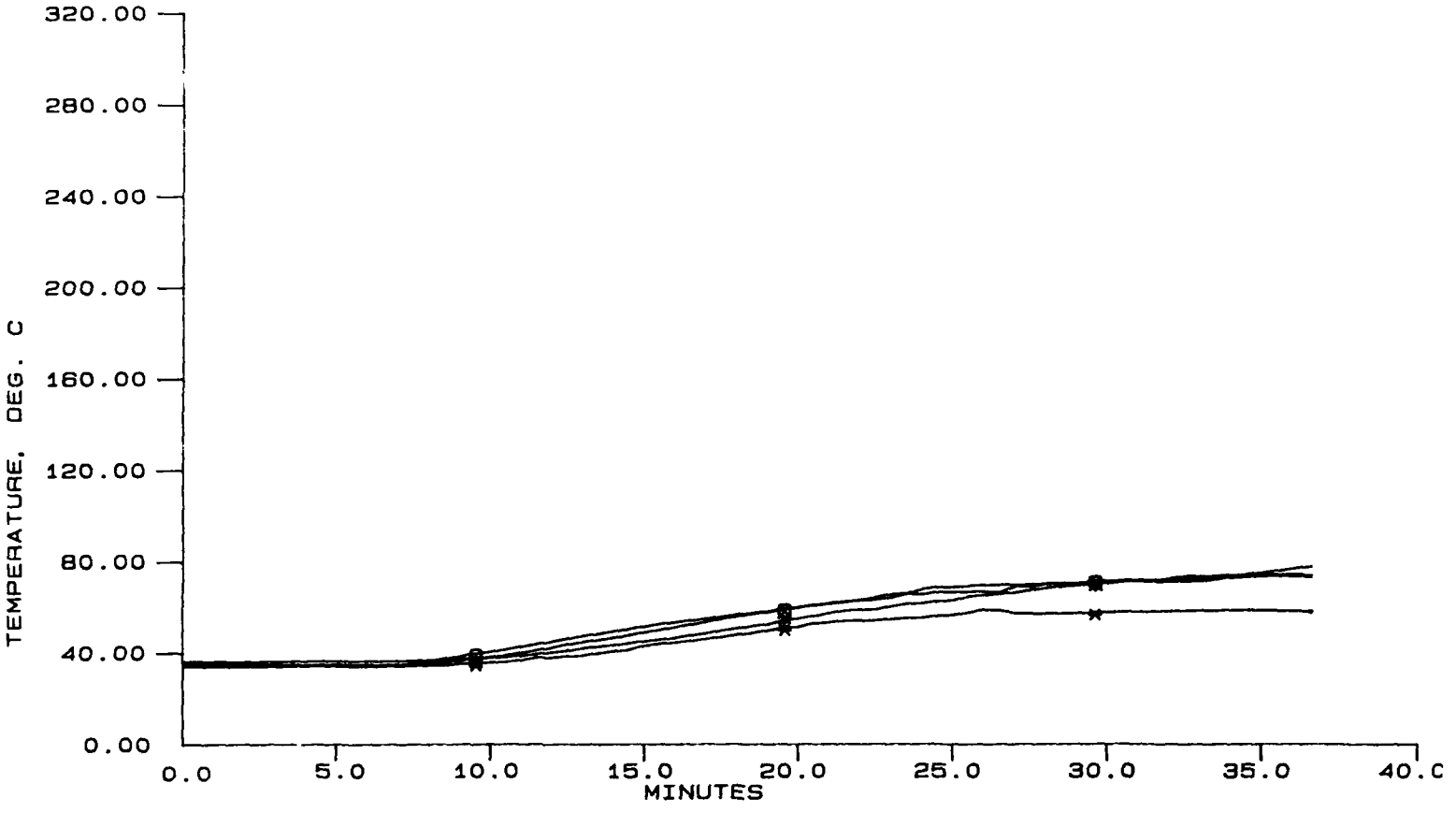


Fig. B-41 SMOKE CURTAIN TEST W-37 LEVEL 01 CH 64 O , 65 X , 66 + , 67 X

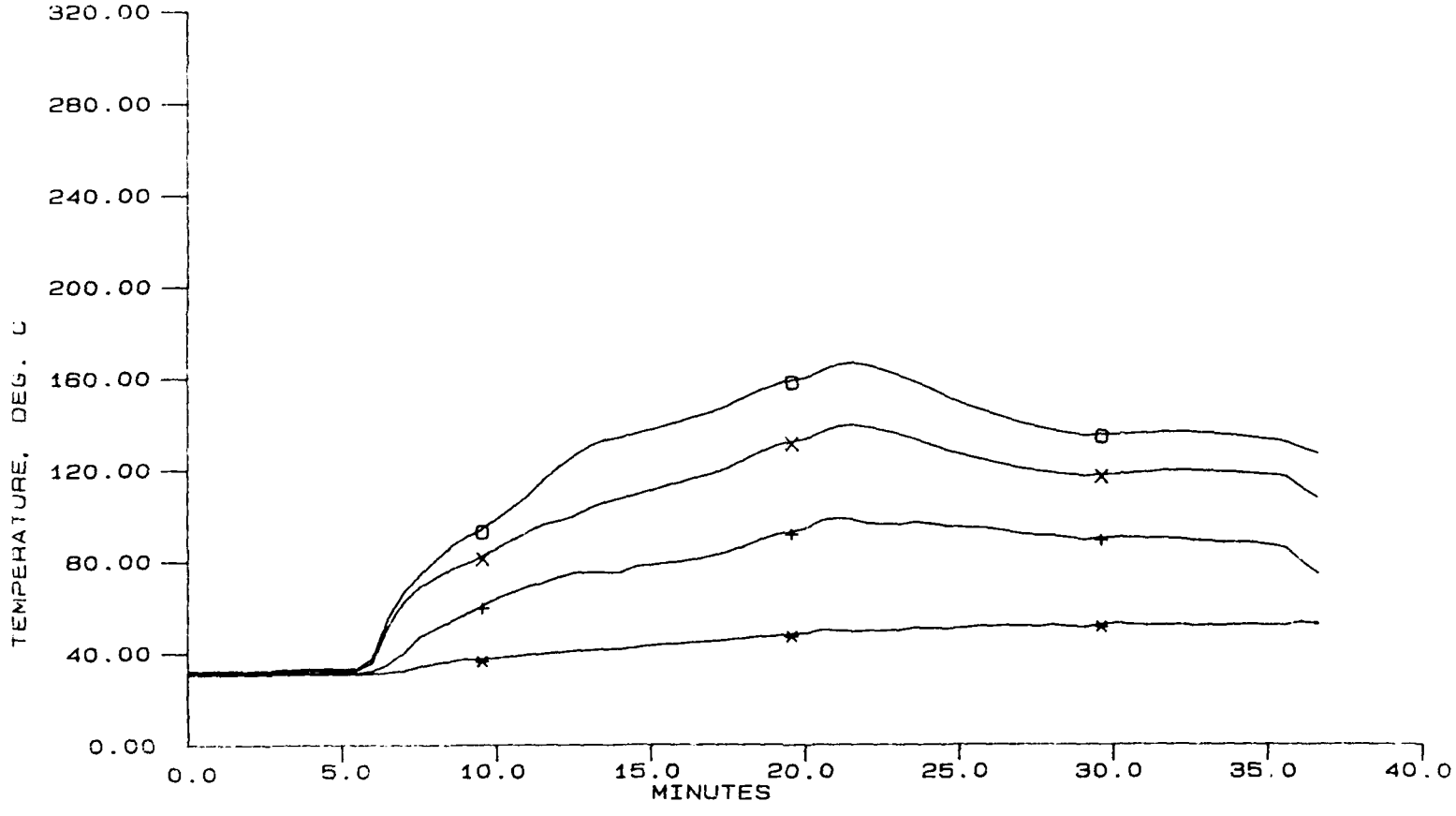


Fig. B-42 SMOKE CURTAIN TEST W-37 LEVEL 01 CH 60 ○, 61 X, 62 +, 63 ✳

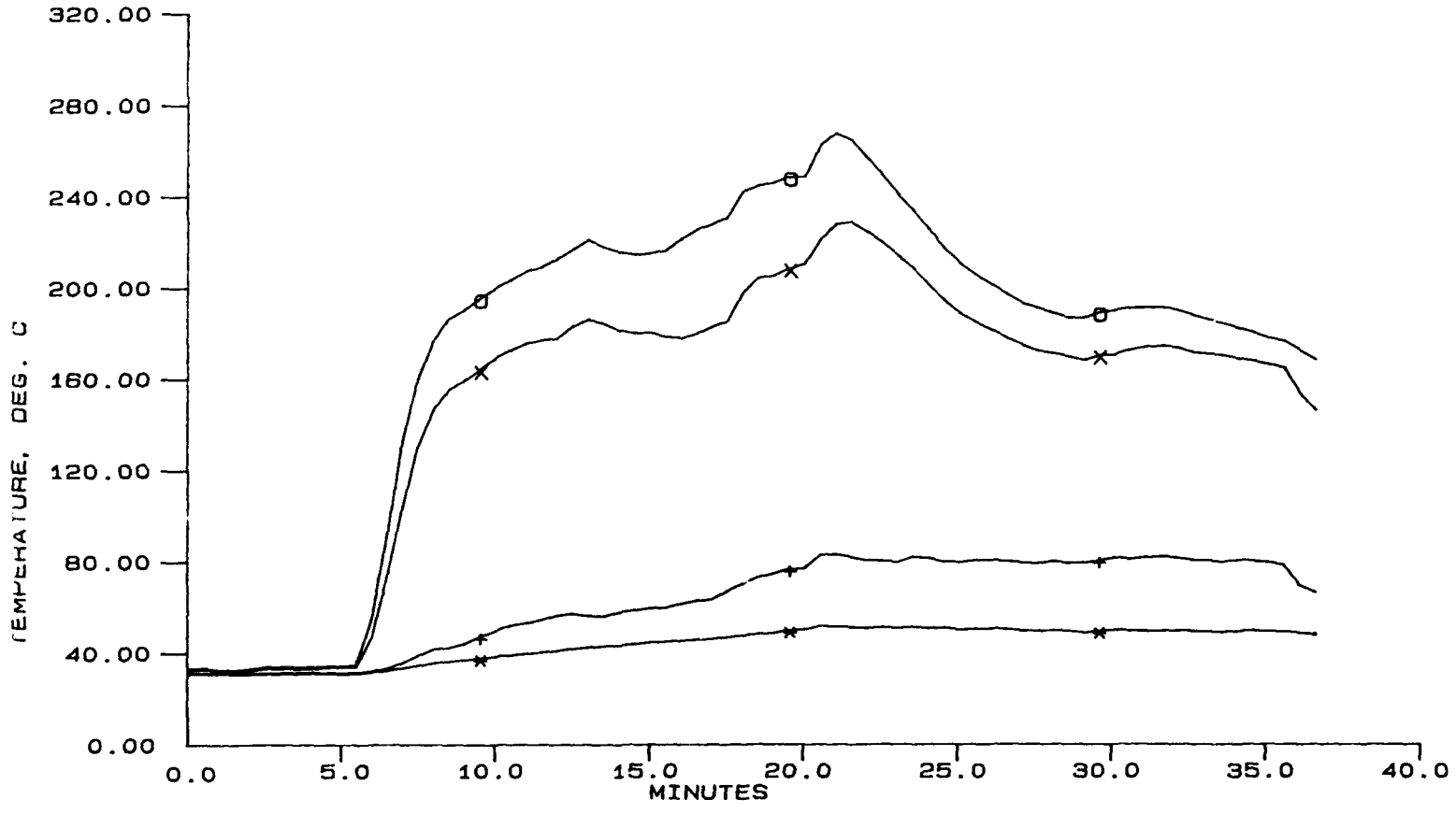


Fig. B-43 SMOKE CURTAIN TEST W-37 LEVEL 01 CH 68 O, 69 X, 70 +, 71 ✳

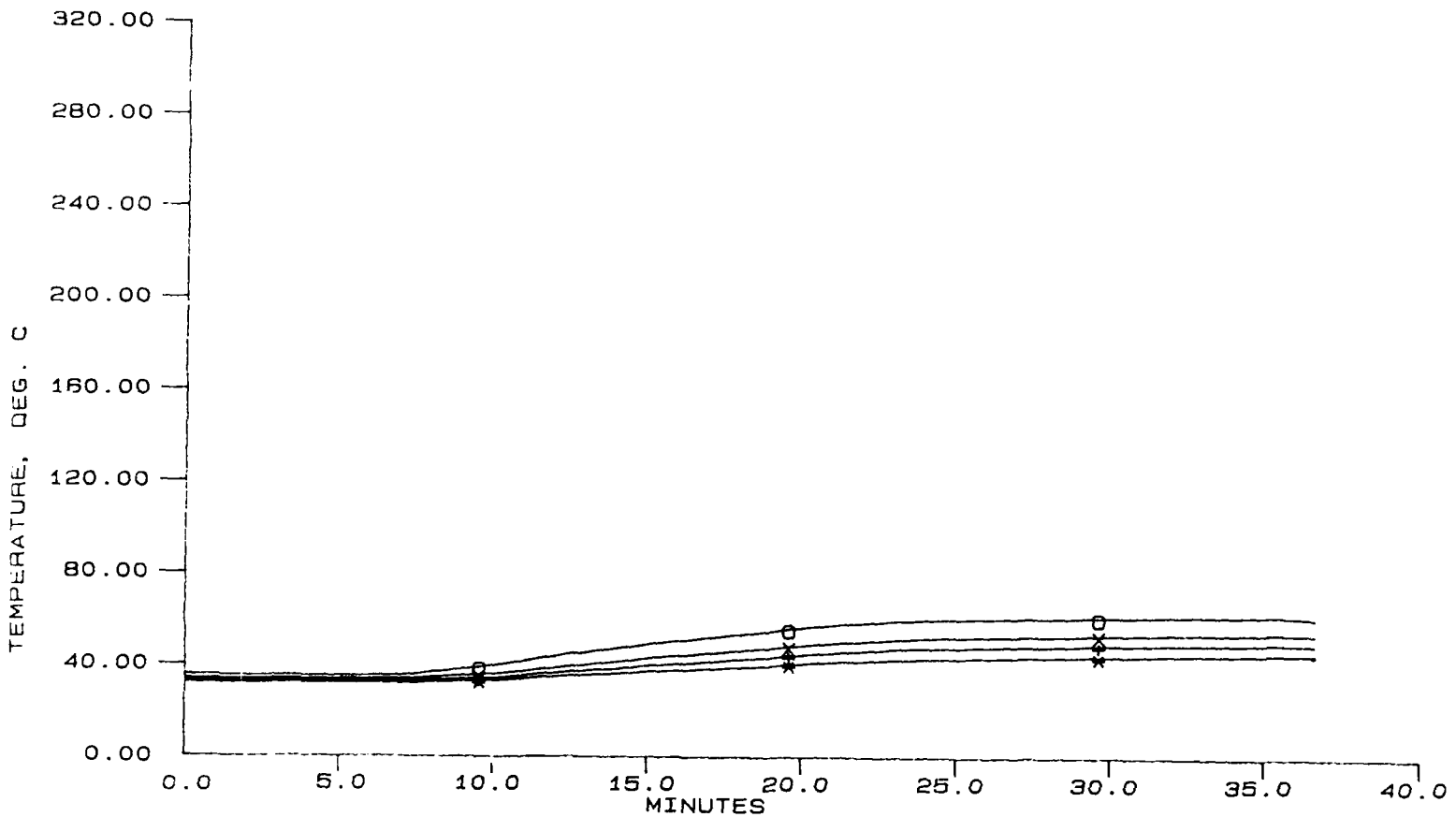


Fig. B-44 SMOKE CURTAIN TEST W-37 LEVEL 01 CH 112 ○, 113 X, 114 +, 115 ✳

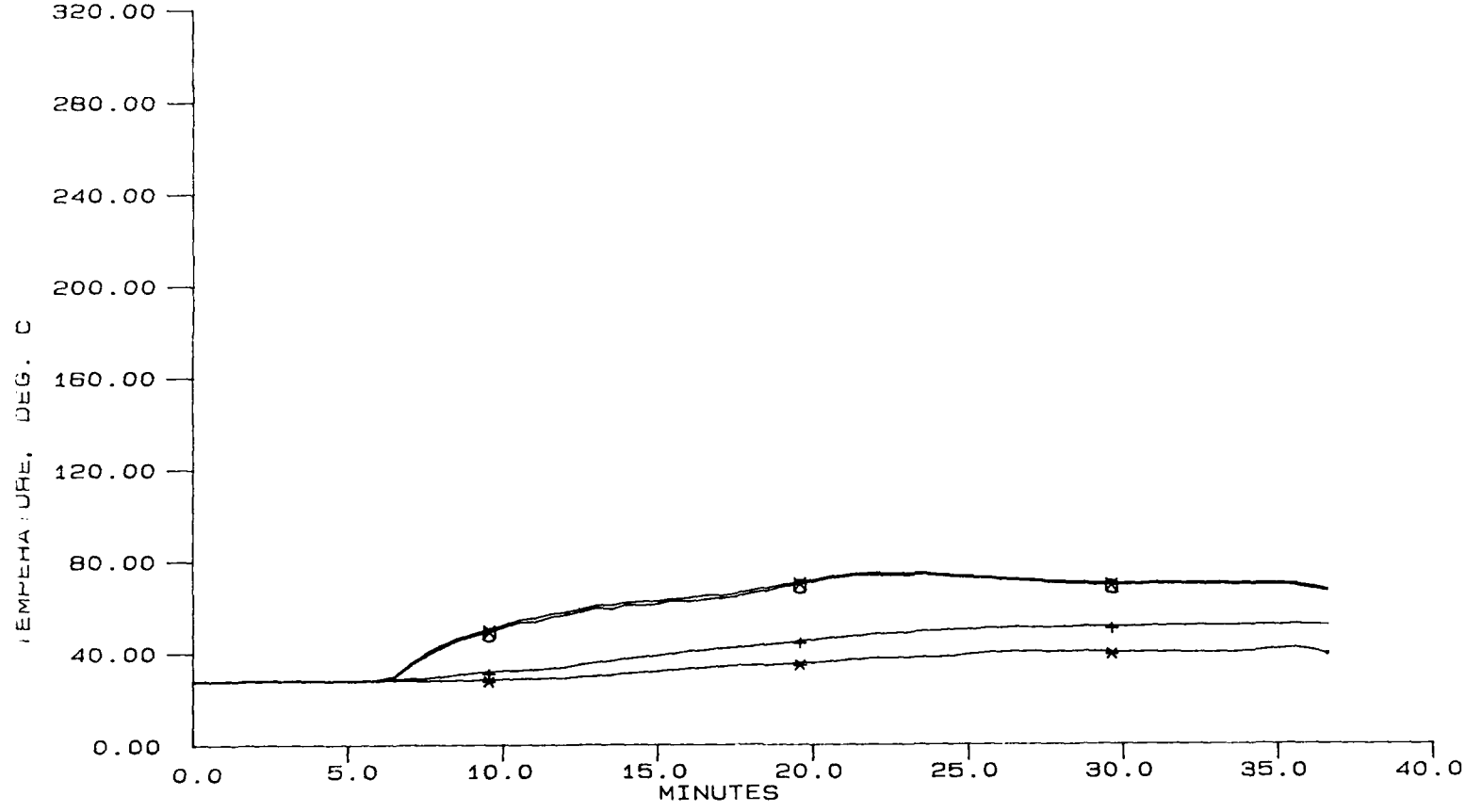


Fig. B-45 SMOKE CURTAIN TEST W-37 LEVEL 01 CH 76 O, 77 X, 78 +, 79 ✳

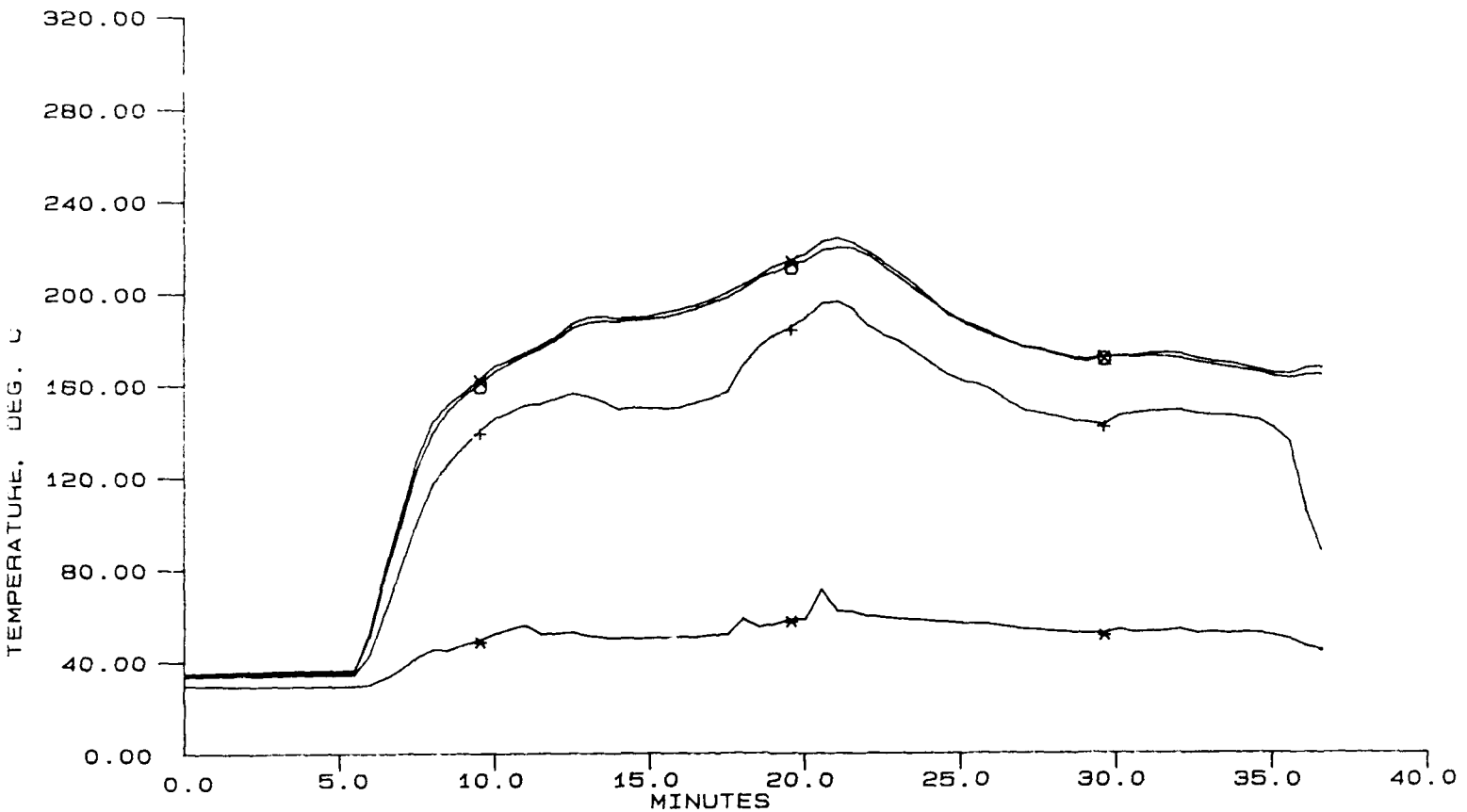


Fig. B-46 SMOKE CURTAIN TEST W-37 LEVEL 01 CH 80 ○, 81 ×, 82 +, 83 ✳

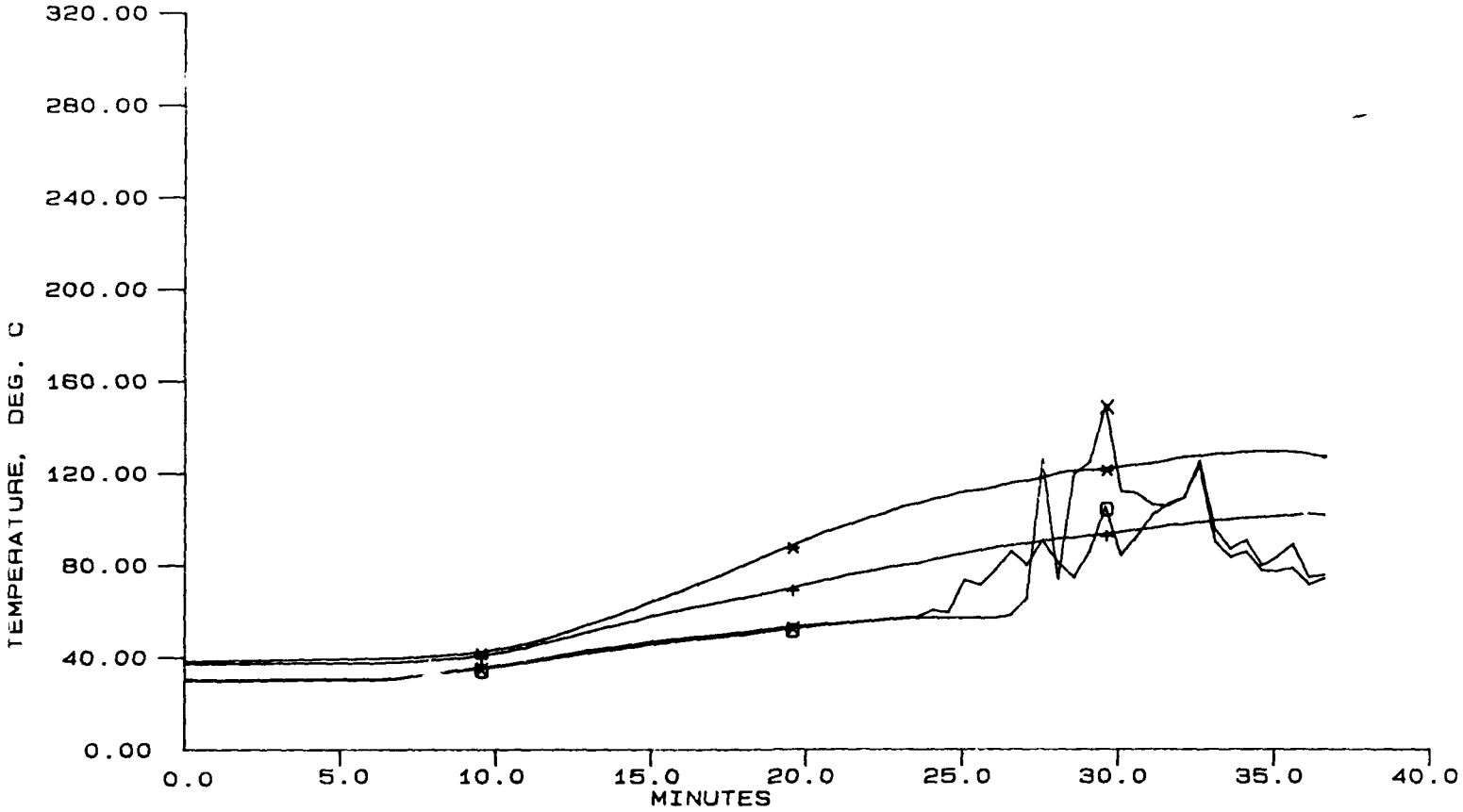


Fig. B-47 SMOKE CURTAIN TEST W-37 LEVEL 01 CH 84 ○, 85 X, 86 +, 87 X

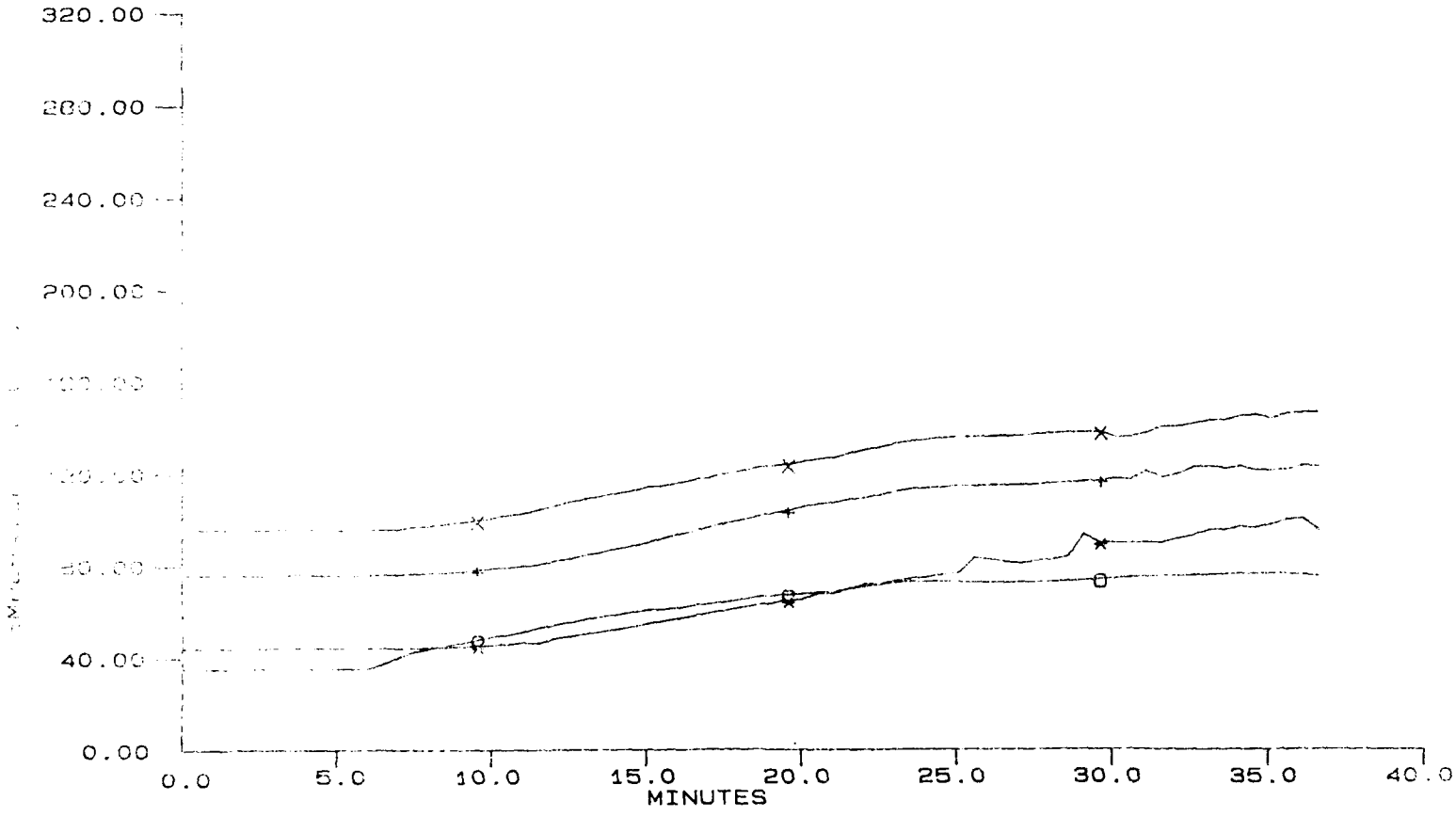


Fig. B-48 SMOKE CURTAIN TEST W-37 MAIN DECK CH 104 ○, 105 X, 106 +, 107 ✳

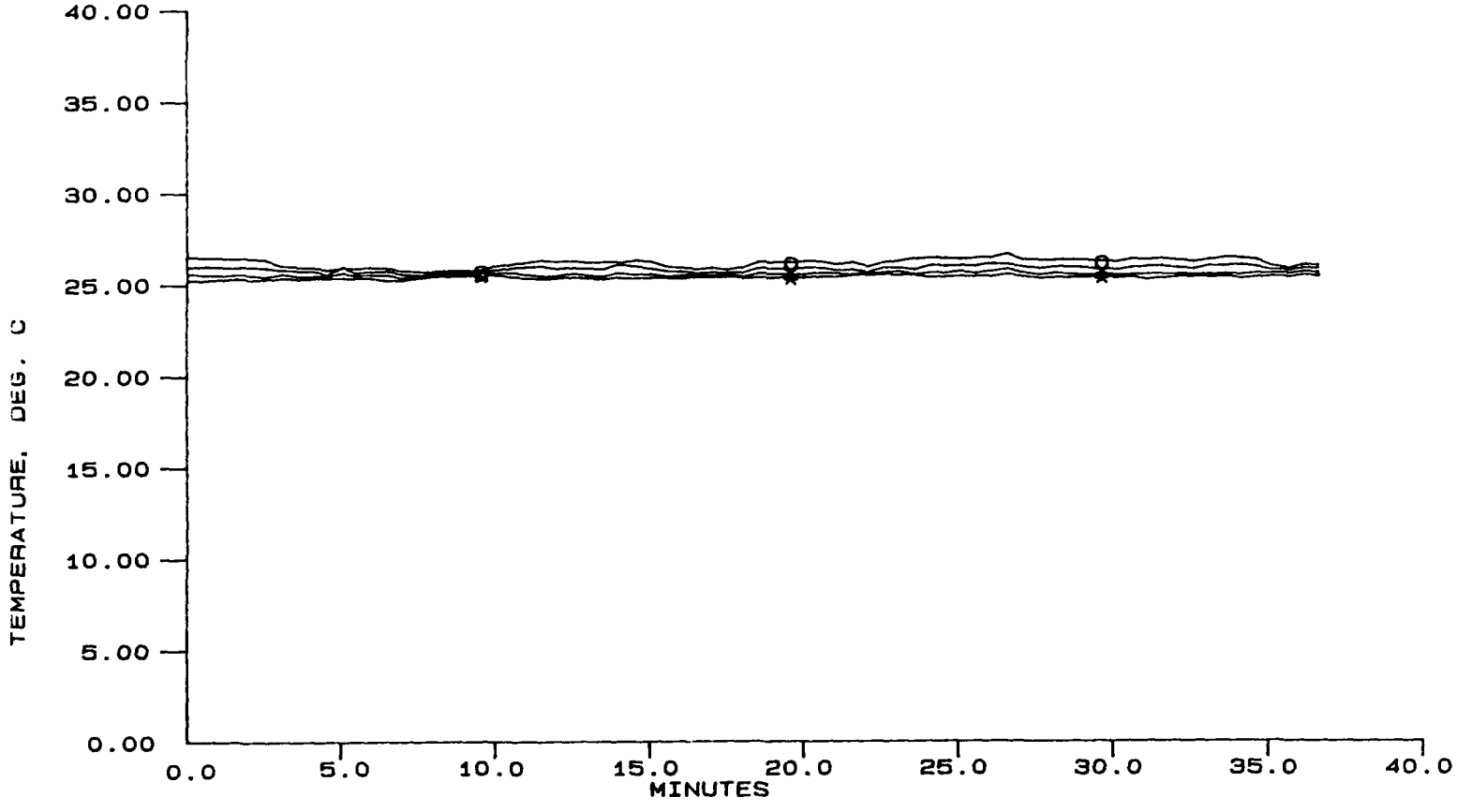


Fig. 49 SMOKE CURTAIN TEST W-37 MAIN DECK CH 100 ○, 101 X, 102 +, 103 ✳

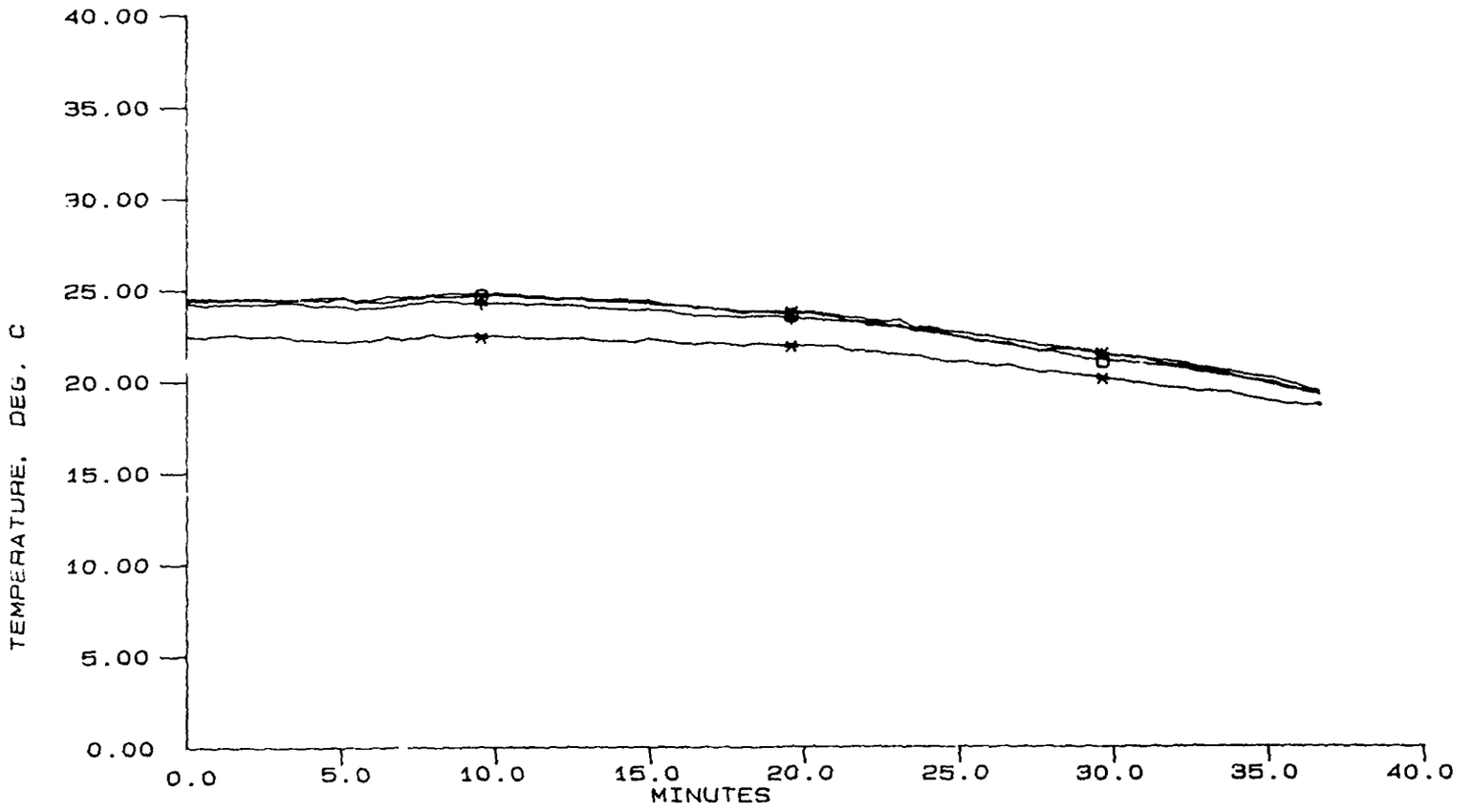


Fig. 50 SMOKE CURTAIN TEST W-37 MAIN DECK CH 108 O, 109 X, 110 +, 111 *

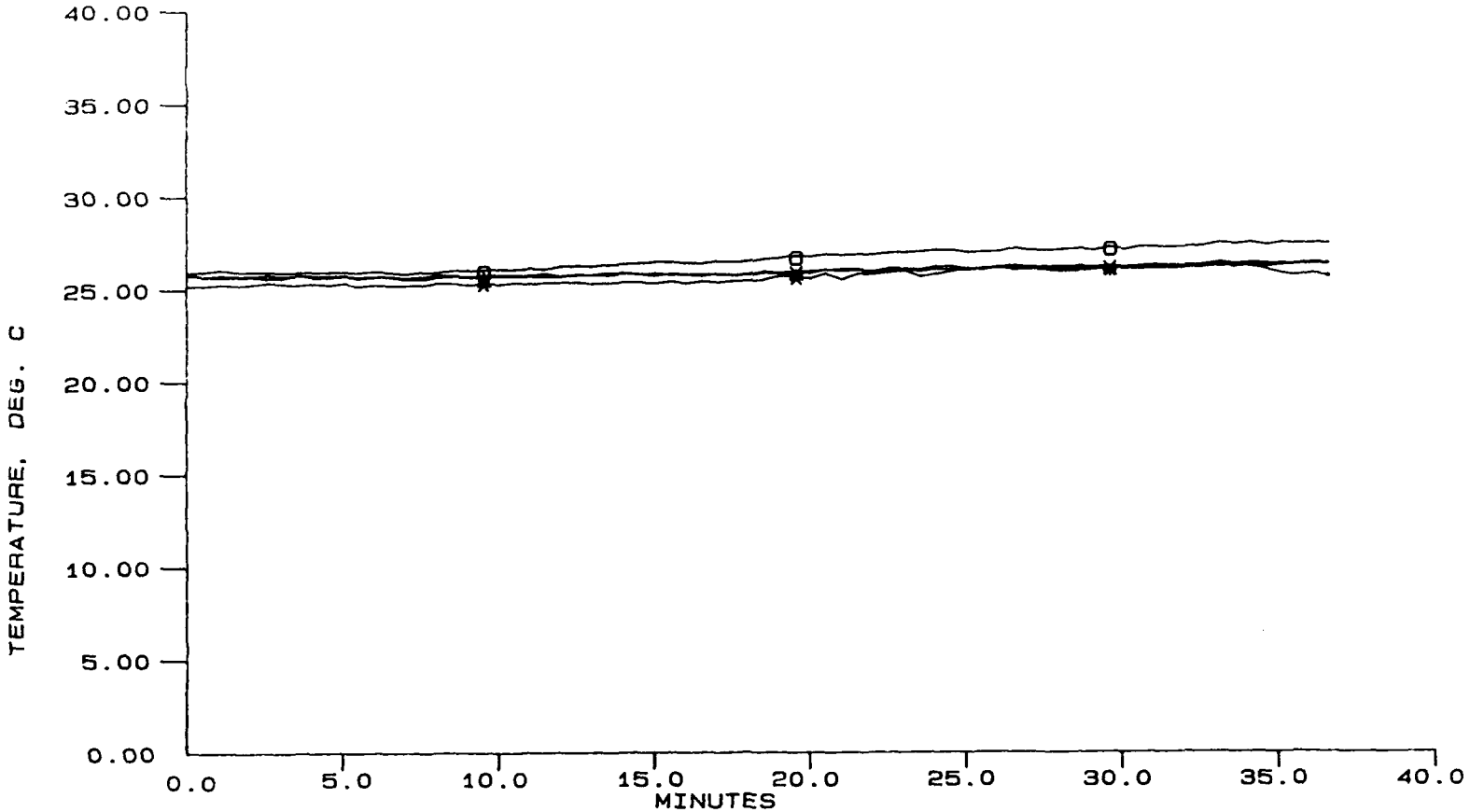
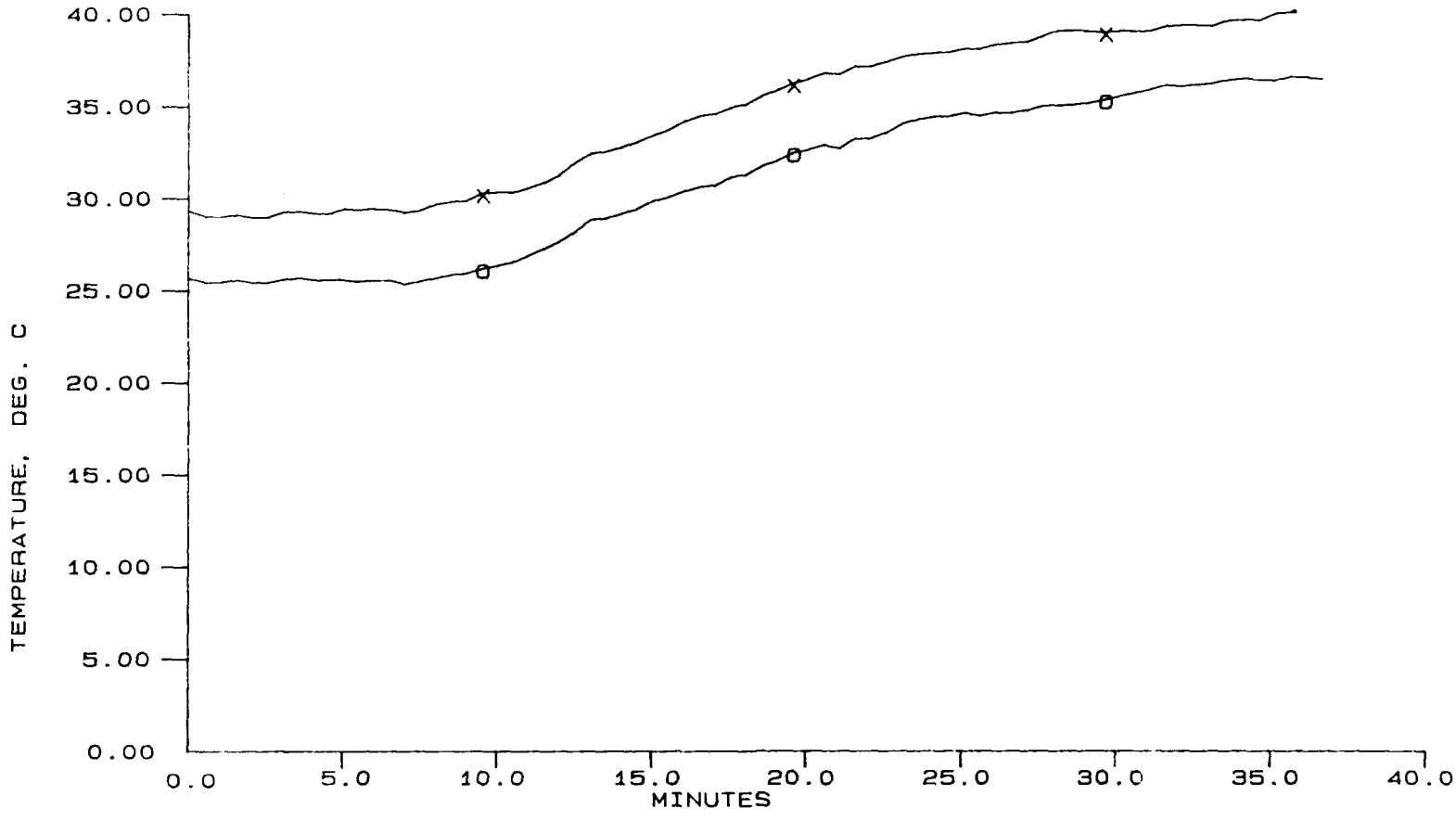


Fig. 51 SMOKE CURTAIN TEST W-37 MAIN DECK CH 94 ○ , 98 X



SMOKE CURTAIN TEST W-38 LEVEL 02 CH 116 ○, 117 ×, 118 +, 118 *
TEMPERATURE, DEG. C
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
MINUTES

Fig. 52

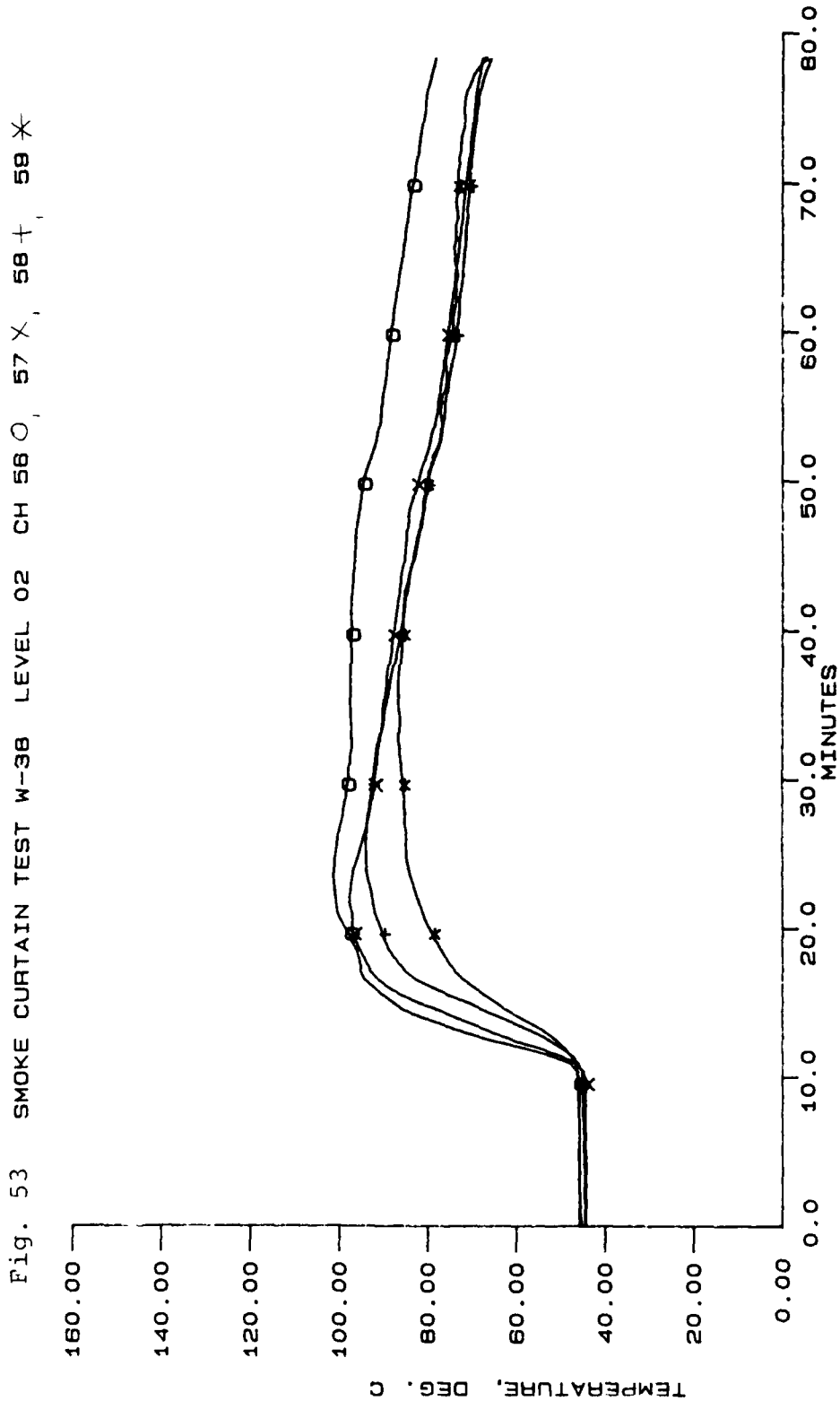

SMOKE CURTAIN TEST W-38 LEVEL 02 CH 58 O, 57 X, 58 +, 59 *
TEMPERATURE, DEG. C
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
MINUTES

Fig. 53

FIG. 54 SMOKE CURTAIN TEST W-38 LEVEL 02 CH 52 ○, 53 ×, 54 +, 55 ✳

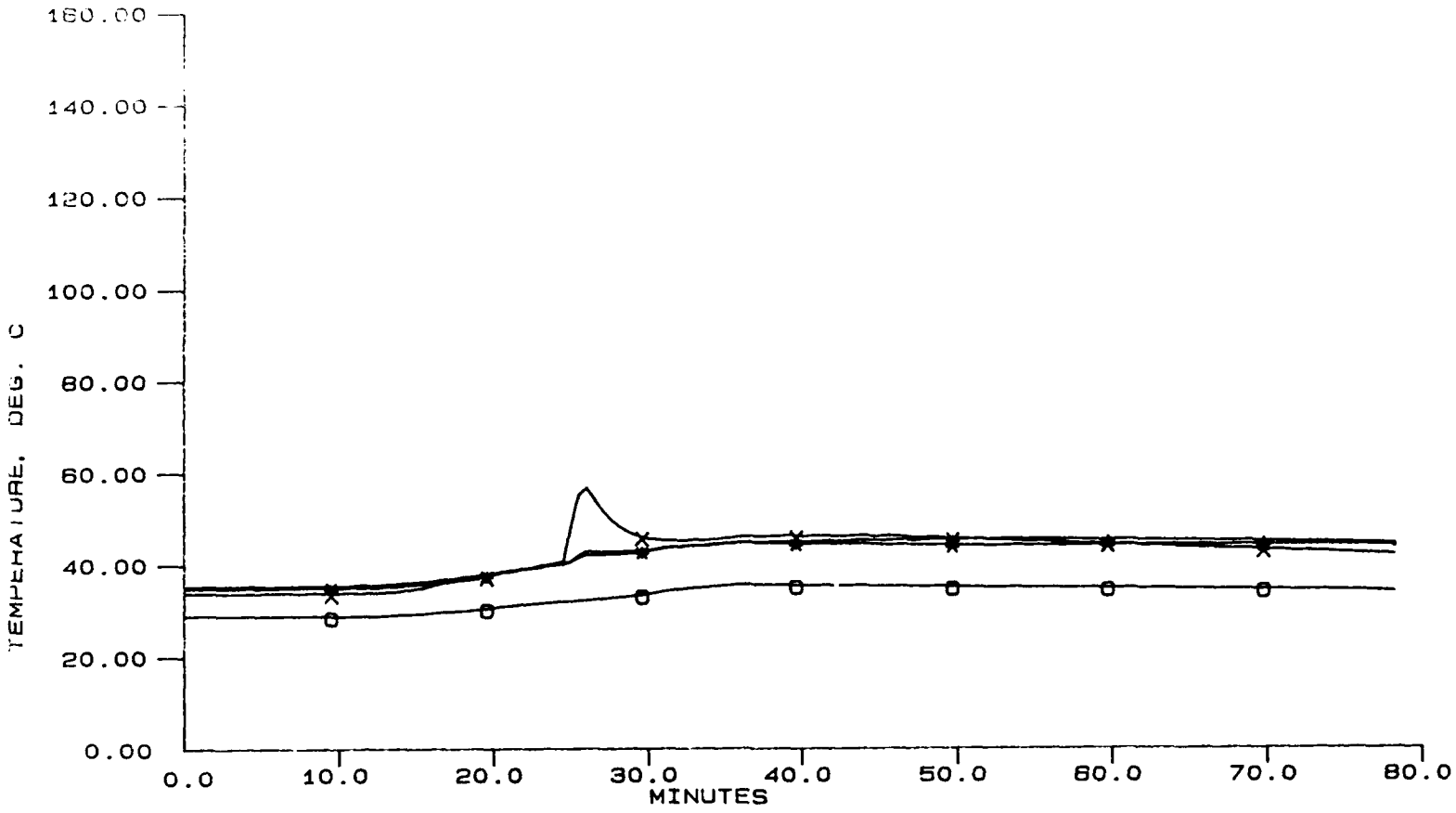


Fig. 55 SMOKE CURTAIN TEST W-38 LEVEL 02 CH 48 ○, 49 X, 50 +, 51 ✳

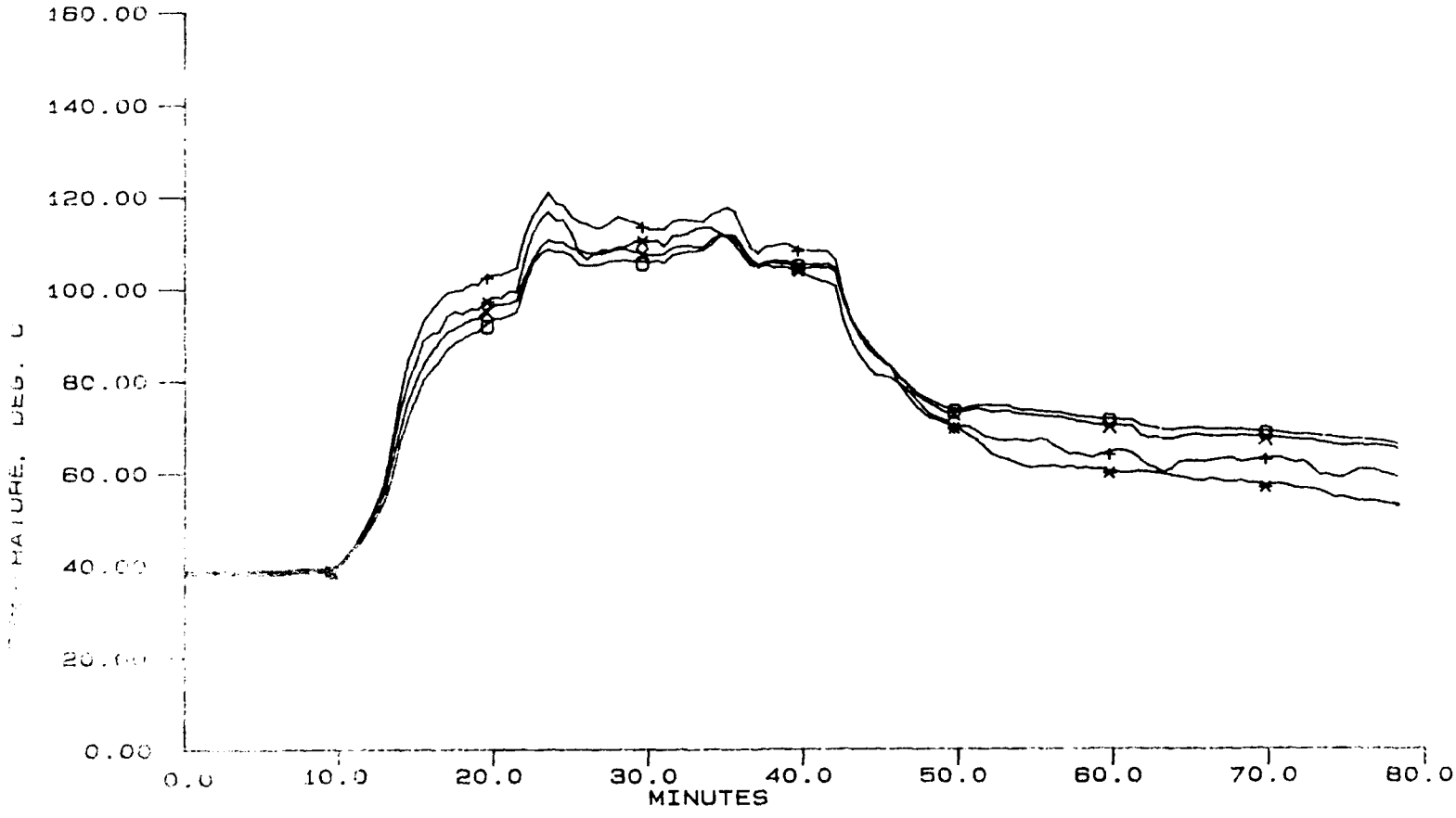


Fig. 56 SMOKE CURTAIN TEST W-38 LEVEL 02 CH 44 O, 45 X, 48 +, 47 ✳

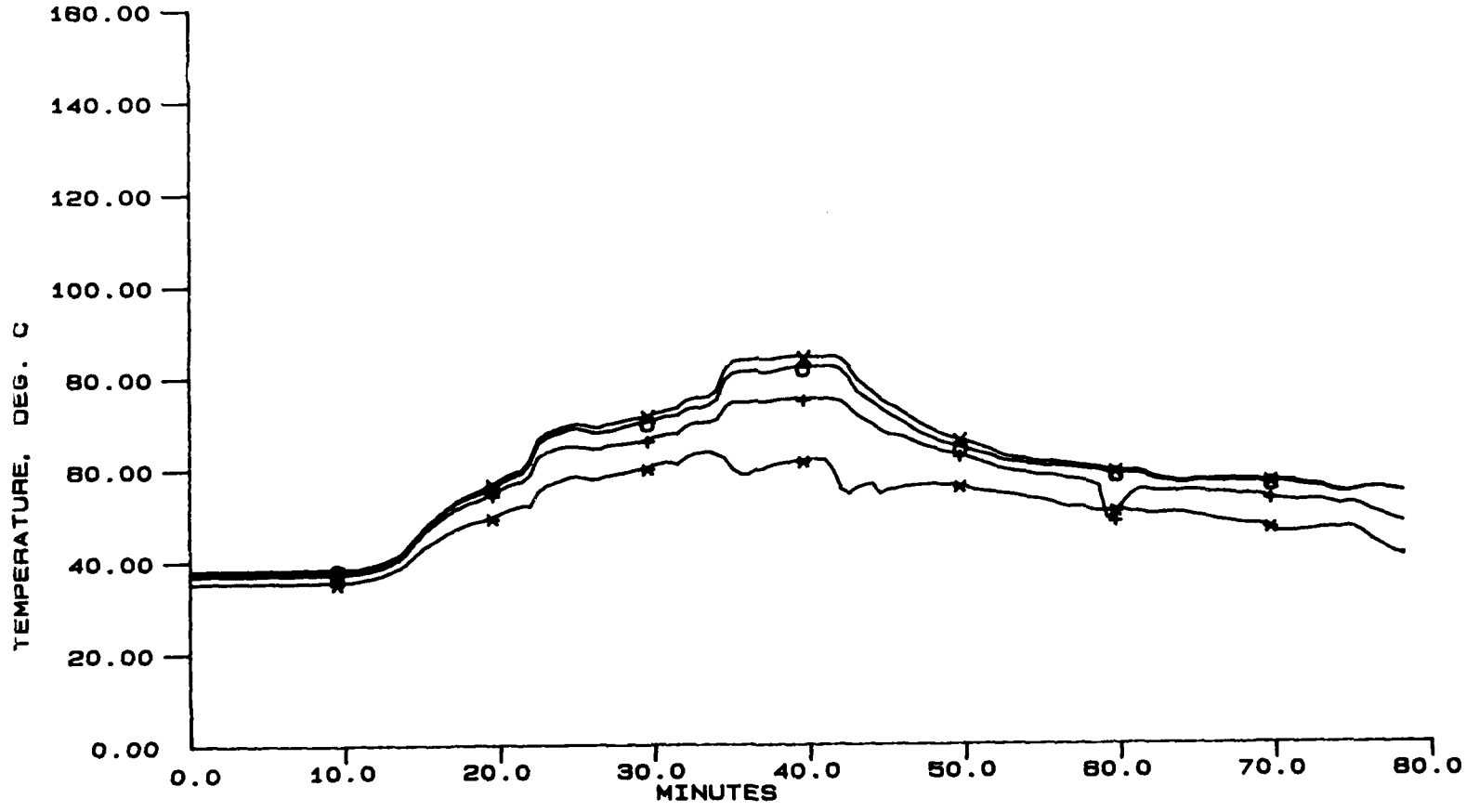


Fig. 57 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 72 ○, 73 X, 74 +, 75 ✳

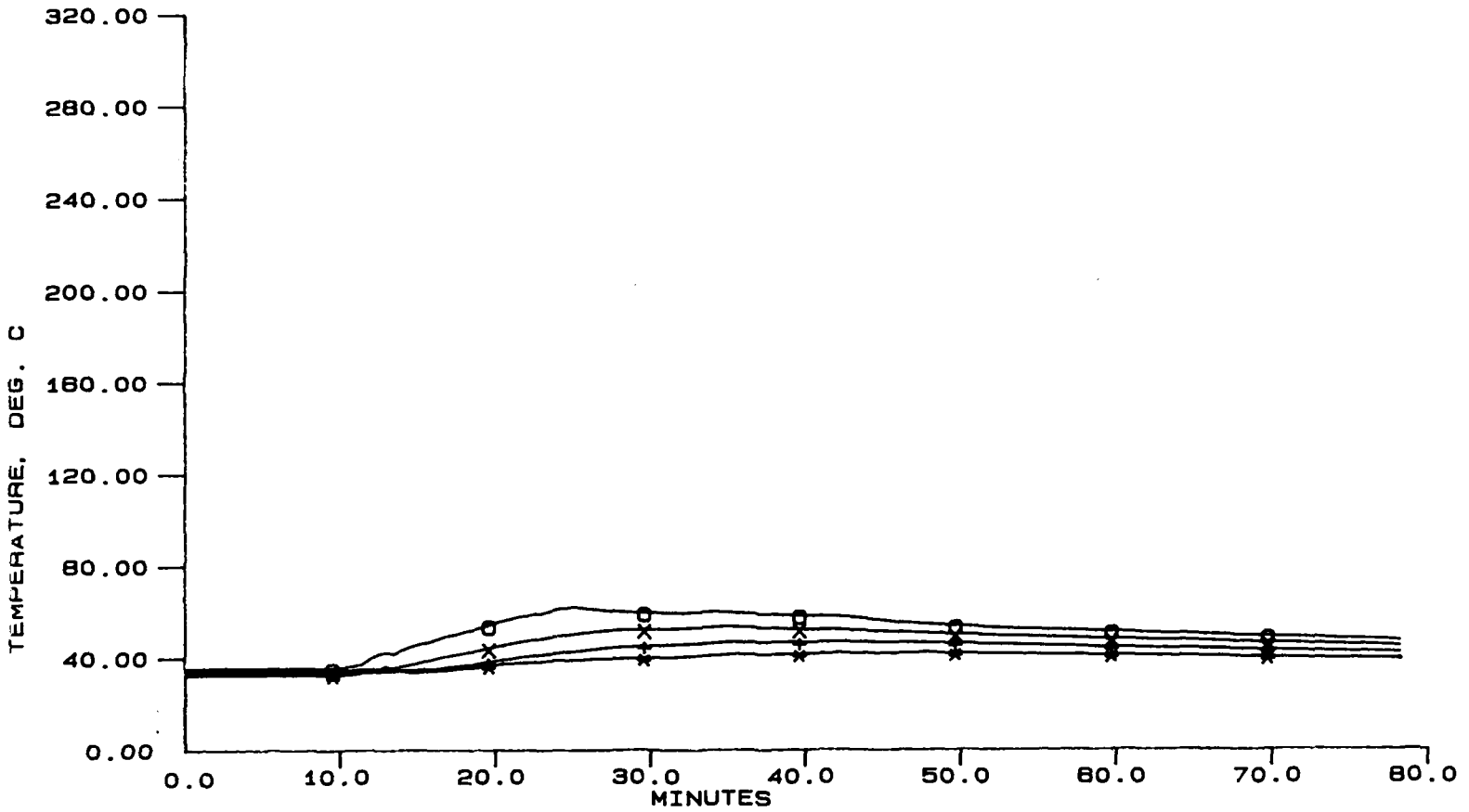


Fig. 58 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 64 ○, 65 X, 66 +, 67 ✳

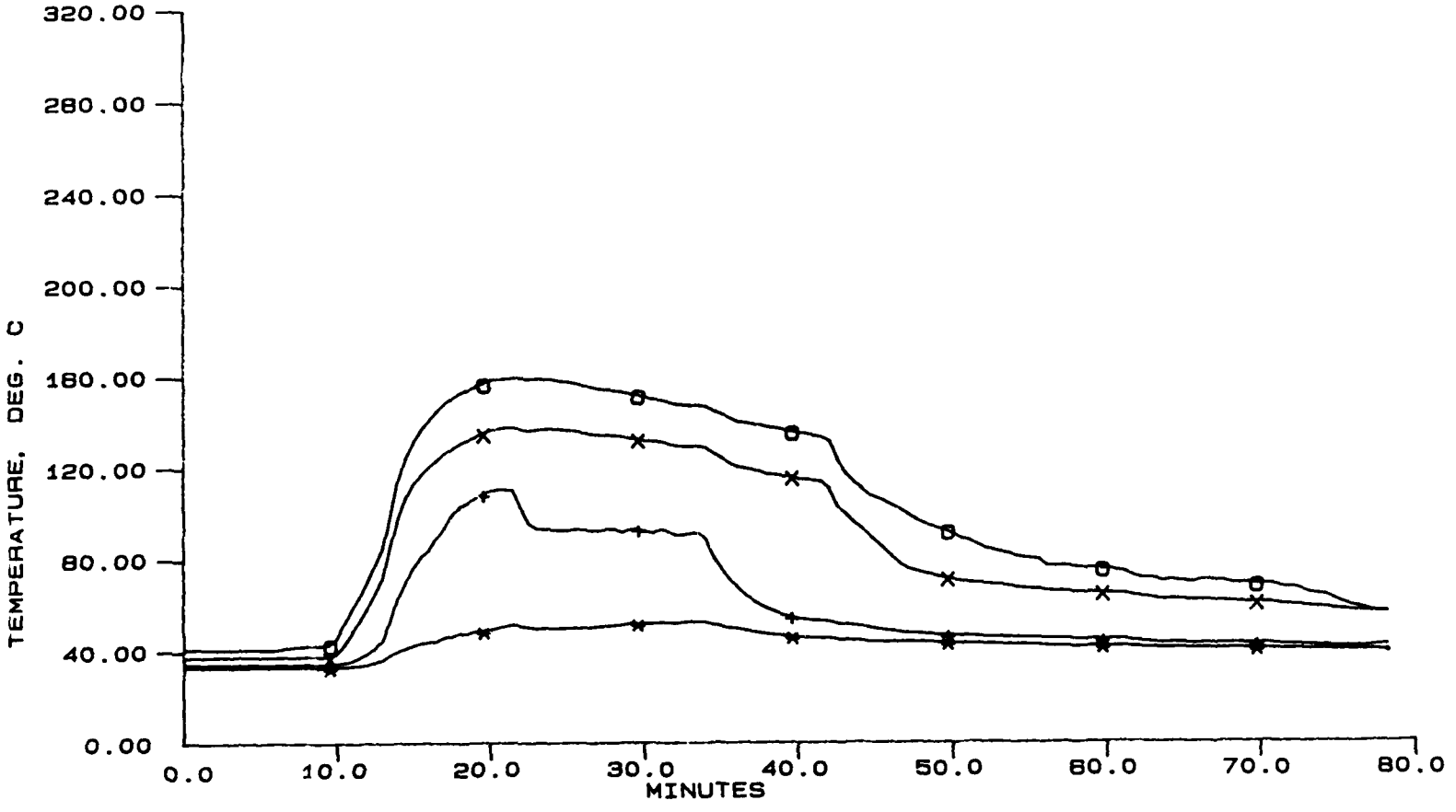


Fig. 59 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 80 ○, 81 X, 82 +, 83 ✳

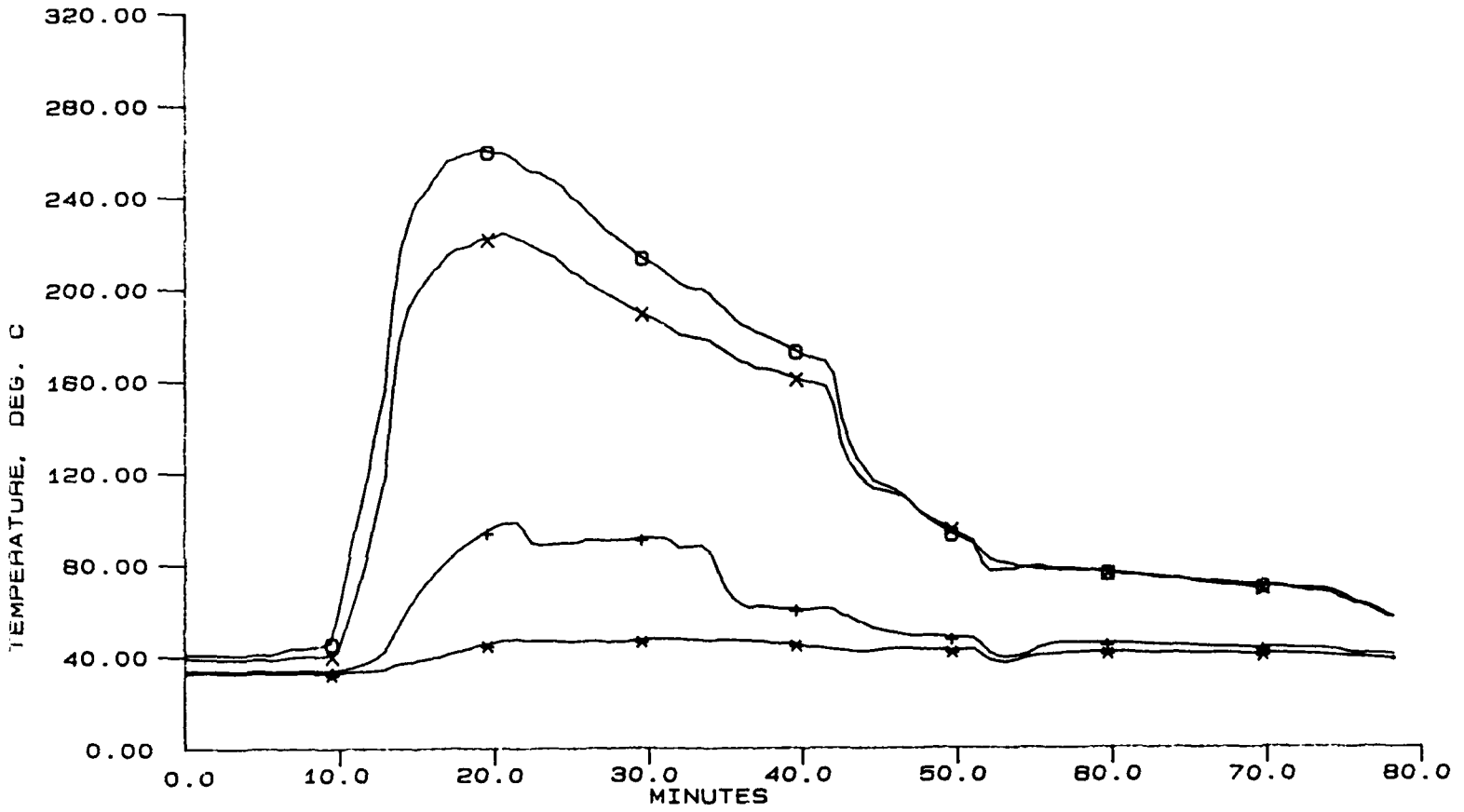


Fig. 60 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 68 ○, 69 X, 70 +, 71 ✳

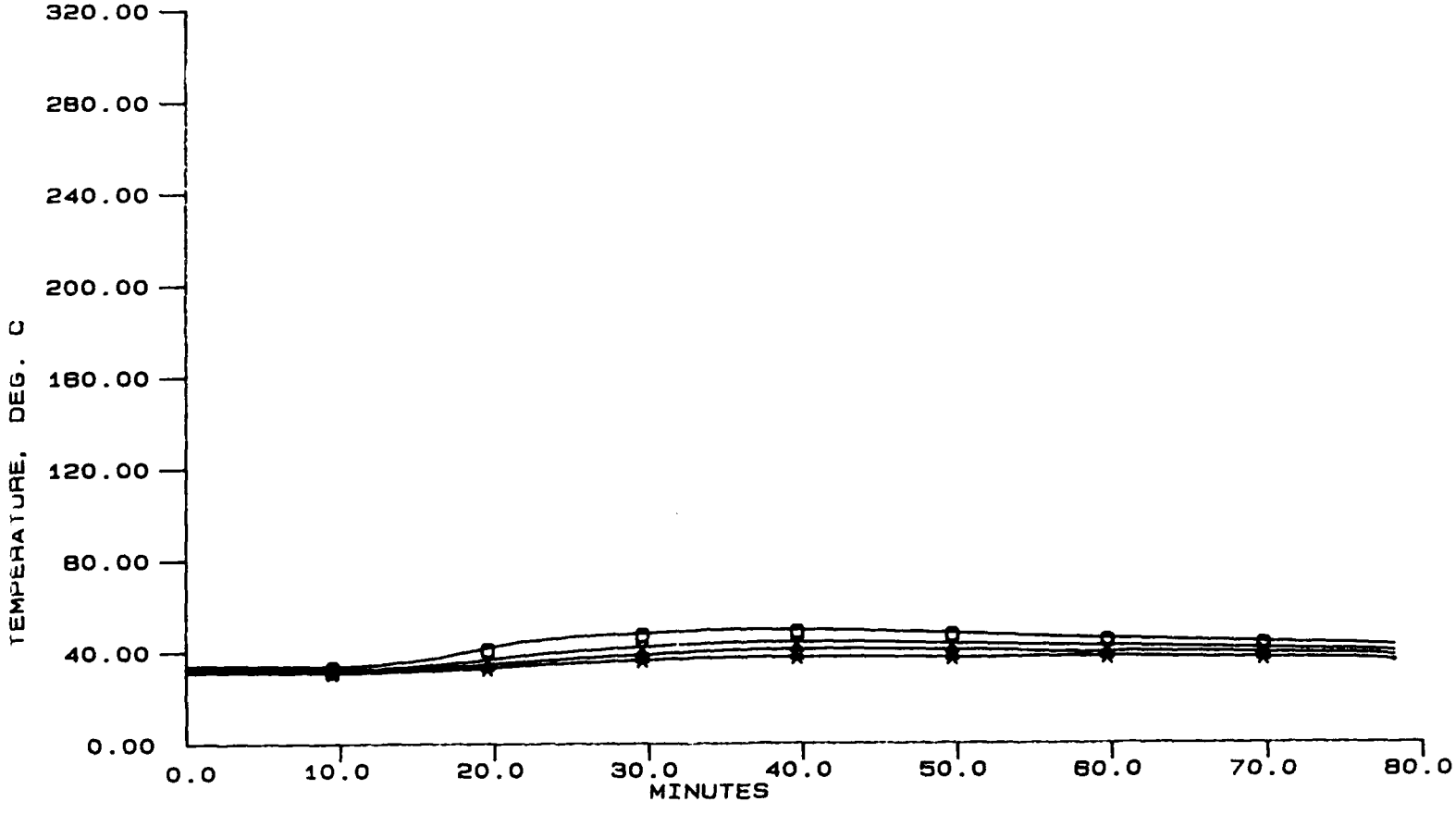


Fig. 61 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 112 ○, 113 X, 114 +, 115 ✳

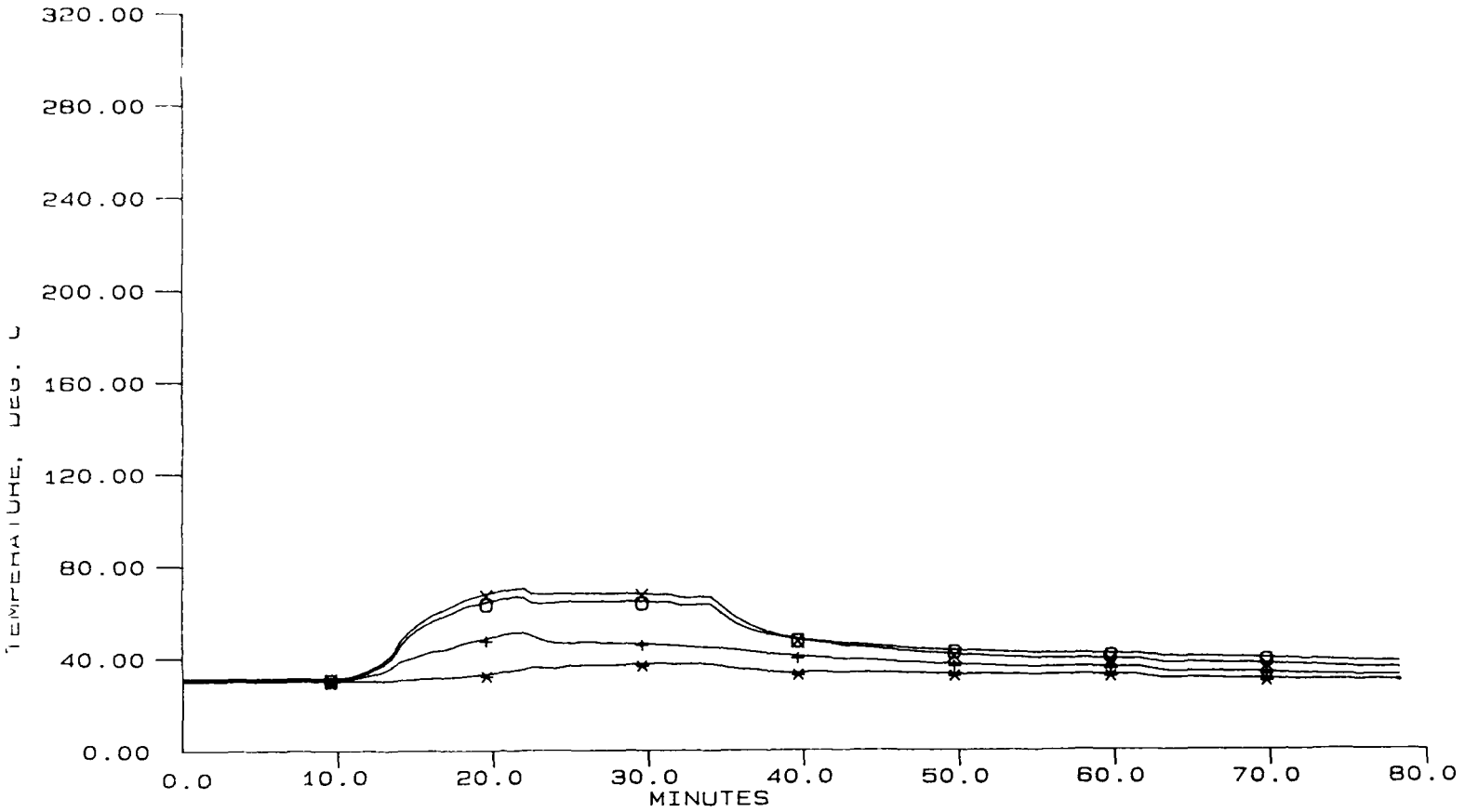


Fig. 62 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 76 ○, 77 X, 78 +, 79 ✳

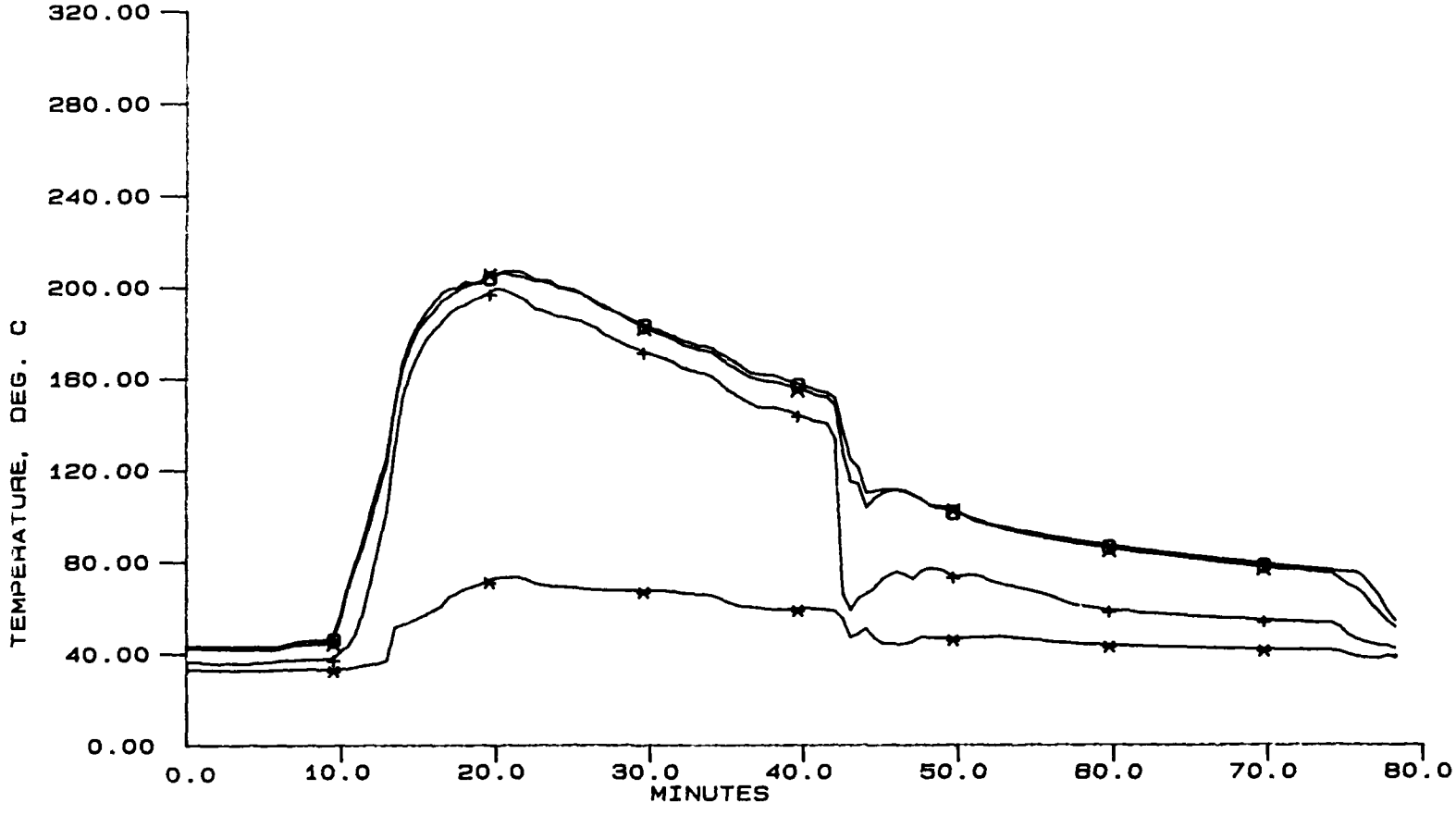


Fig. 63 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 80 O, 81 X, 82 +, 83 *

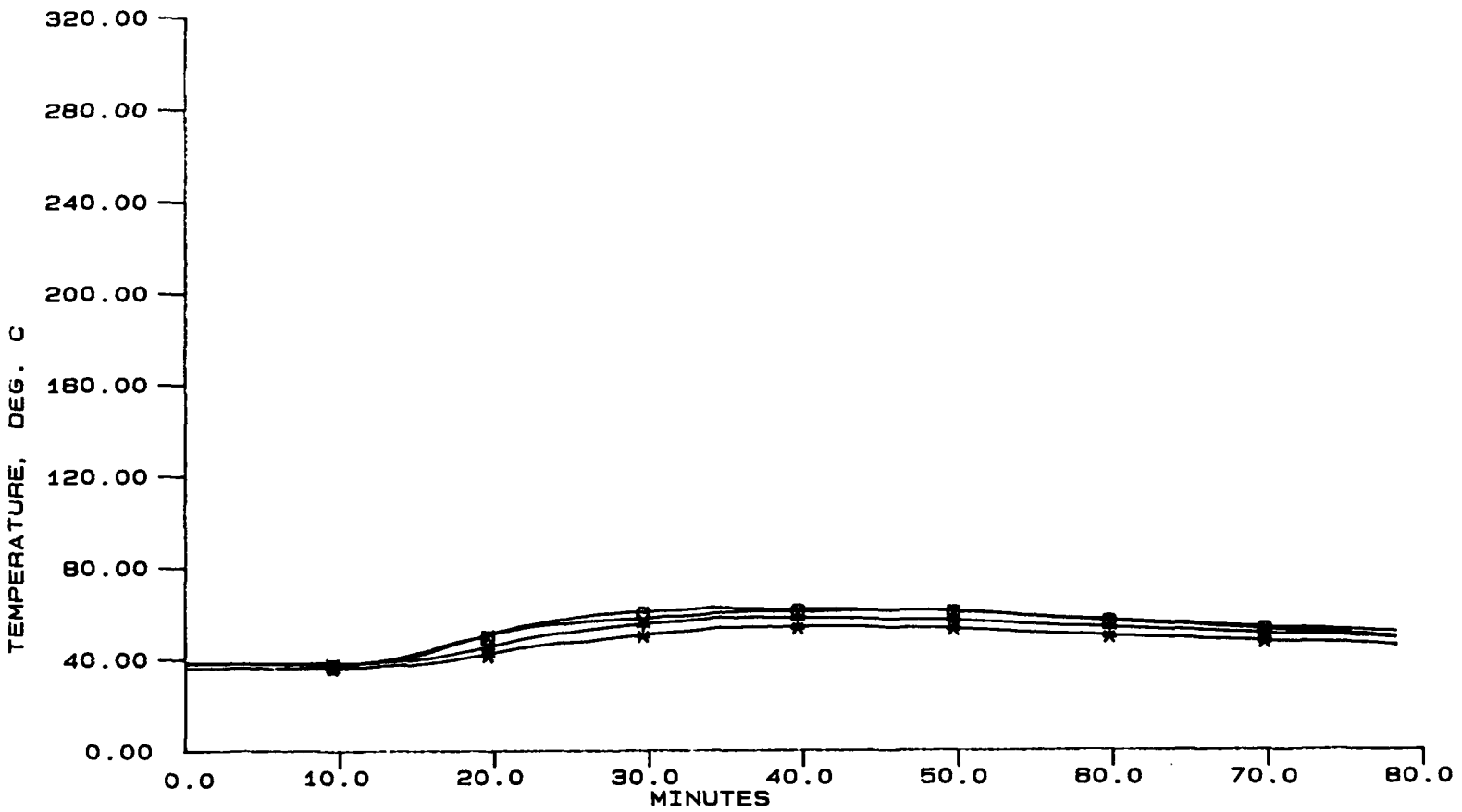


Fig. 64 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 84 ○, 85 ×, 86 +, 87 ✳

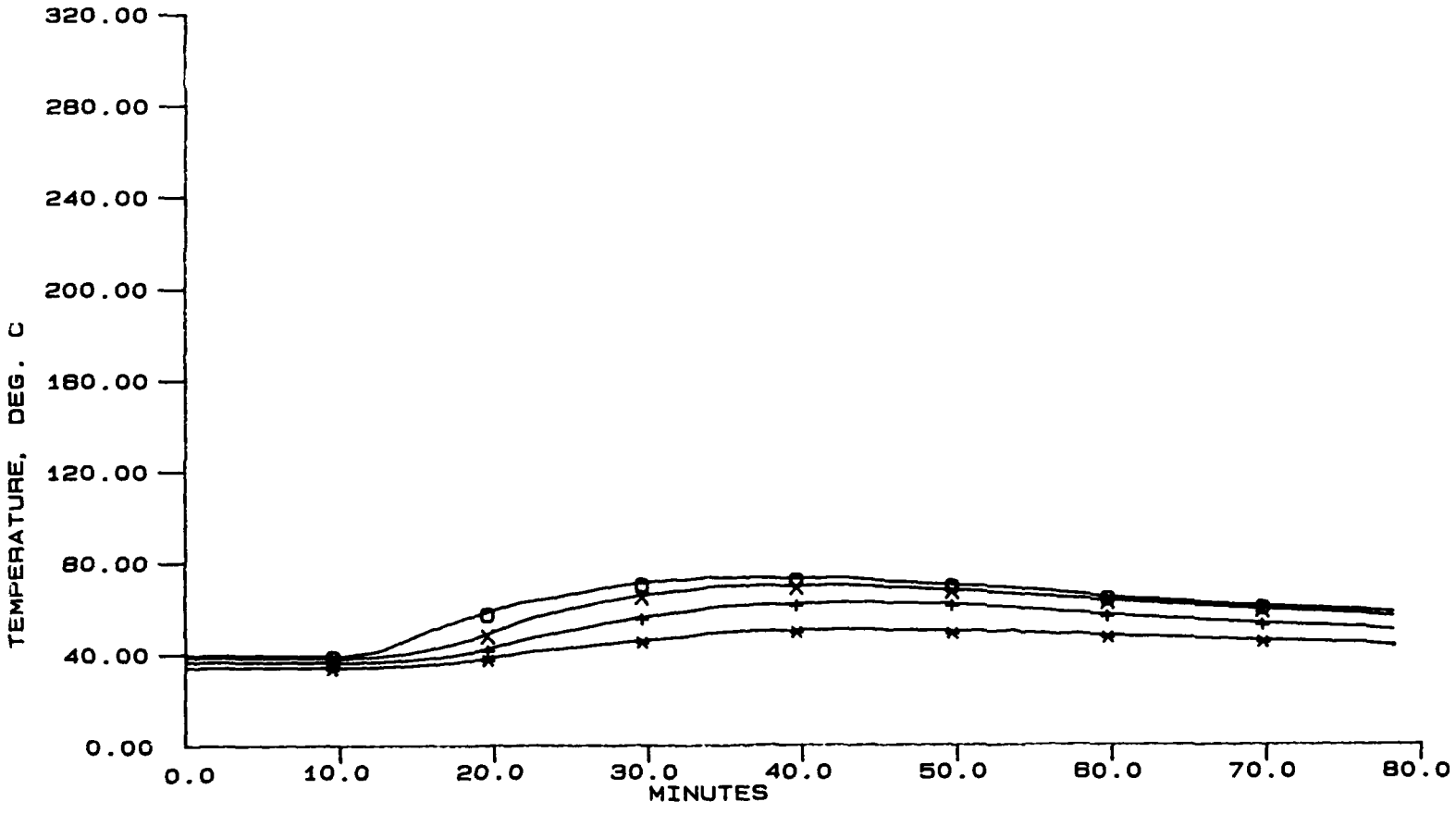


Fig. B-65 SMOKE CURTAIN TEST W-38 MAIN DECK CH 104 ○, 105 X, 106 +, 107 ✳

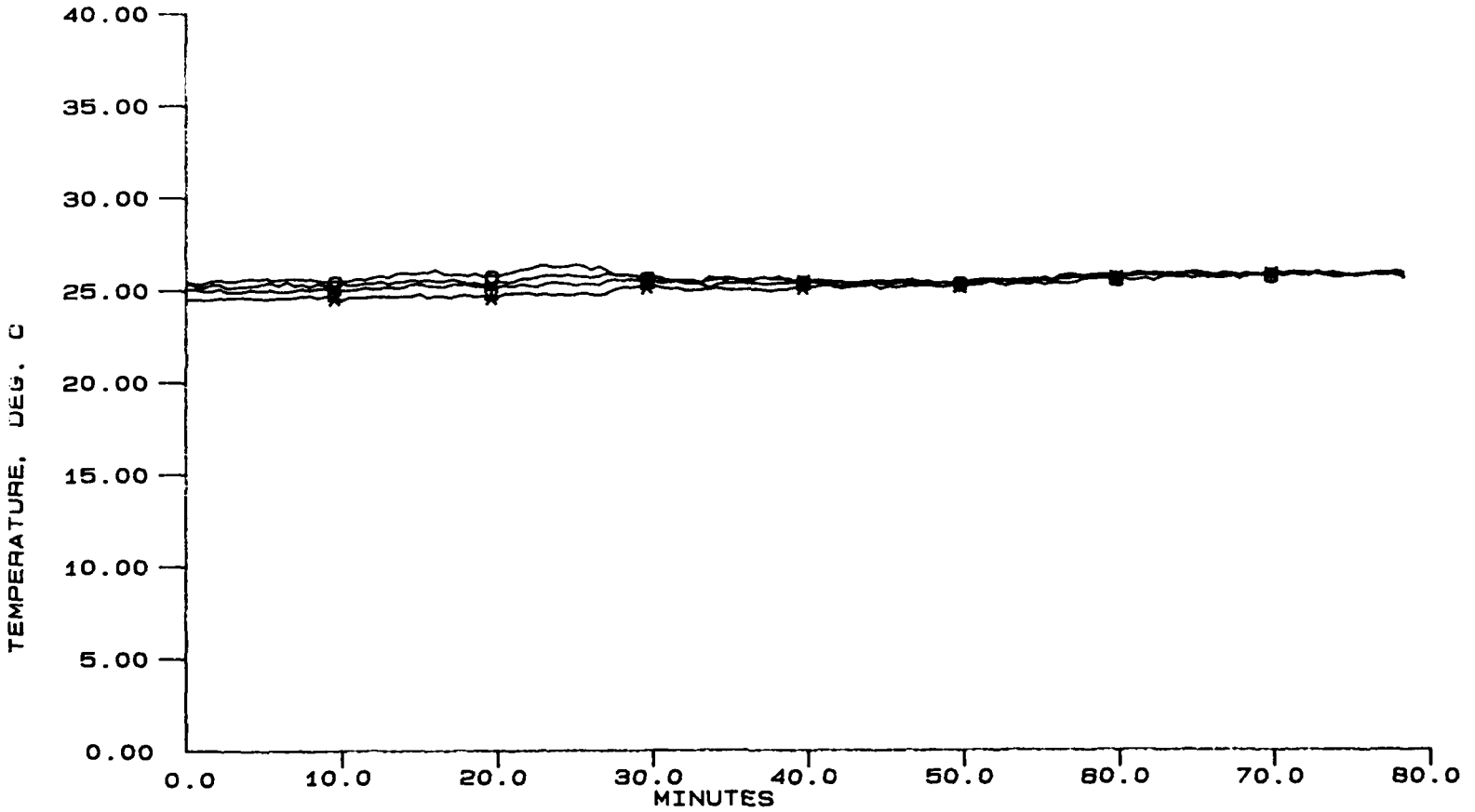


Fig. B-66 SMOKE CURTAIN TEST W-38 MAIN DECK CH 100 ○, 101 ×, 102 +, 103 ✳

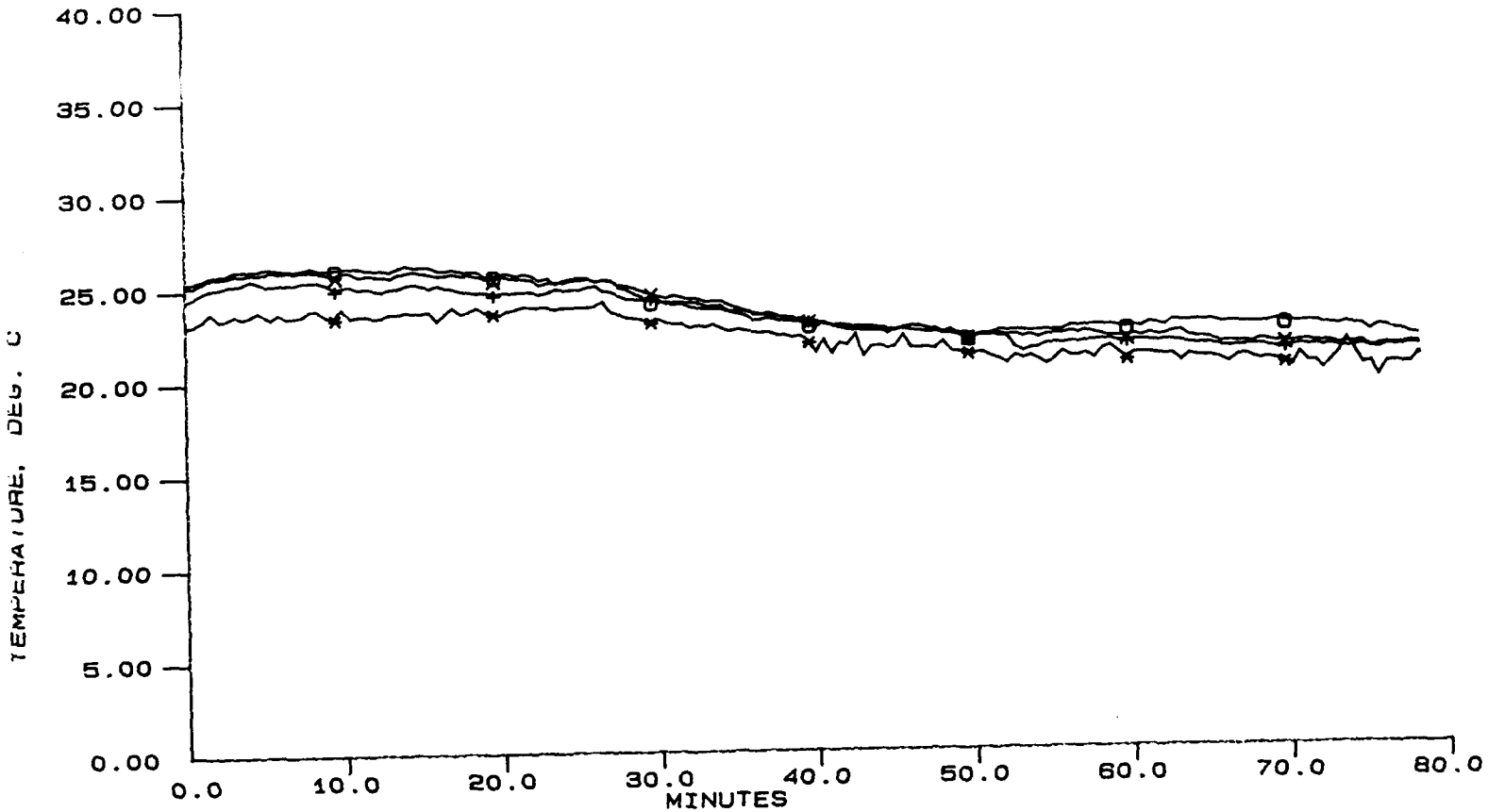


Fig. B-67 SMOKE CURTAIN TEST W-38 MAIN DECK CH 108 ○, 109 ×, 110 +, 111 ✳

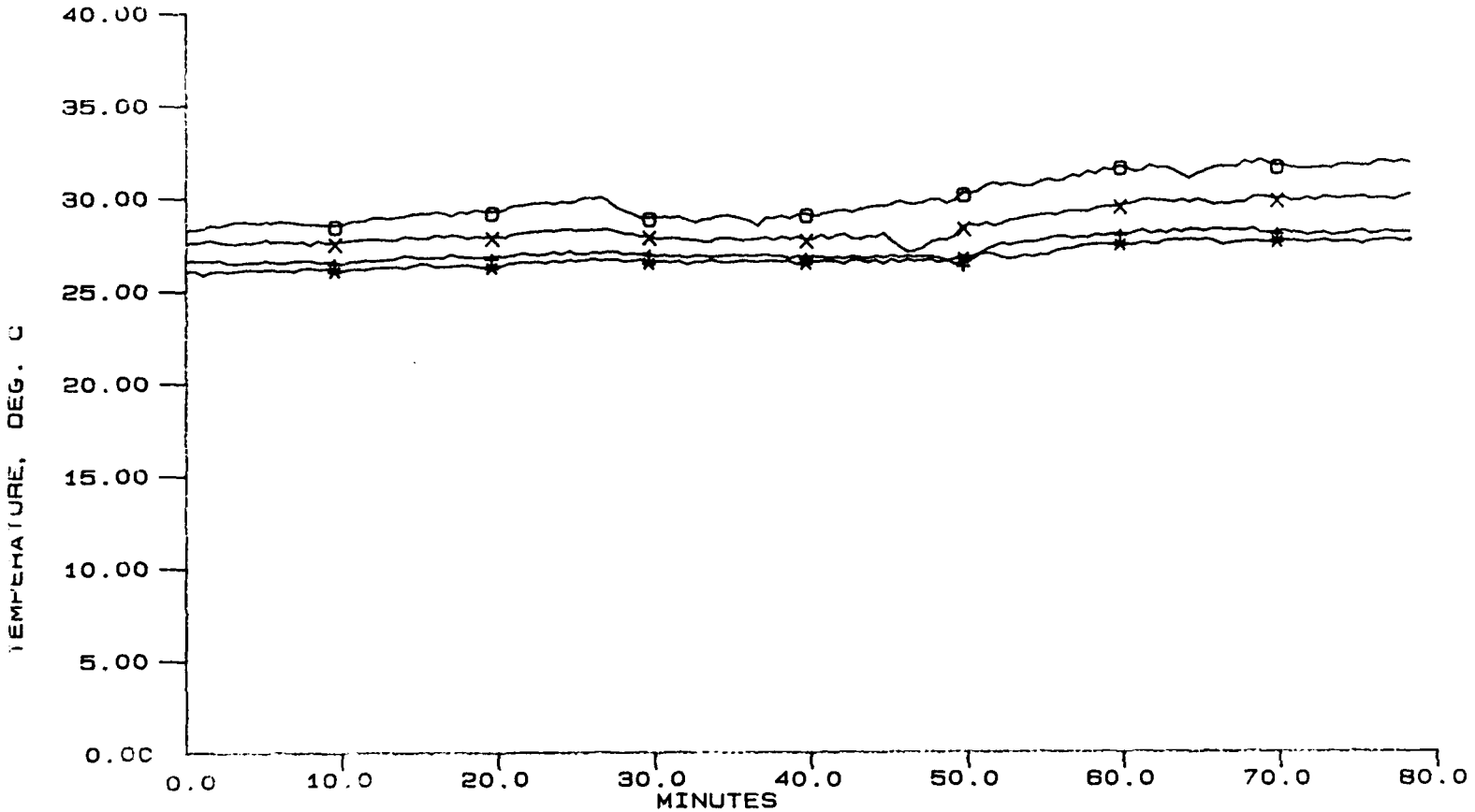


Fig. B-68 SMOKE CURTAIN TEST W-38 MAIN DECK CH 94 ○, 98 ×

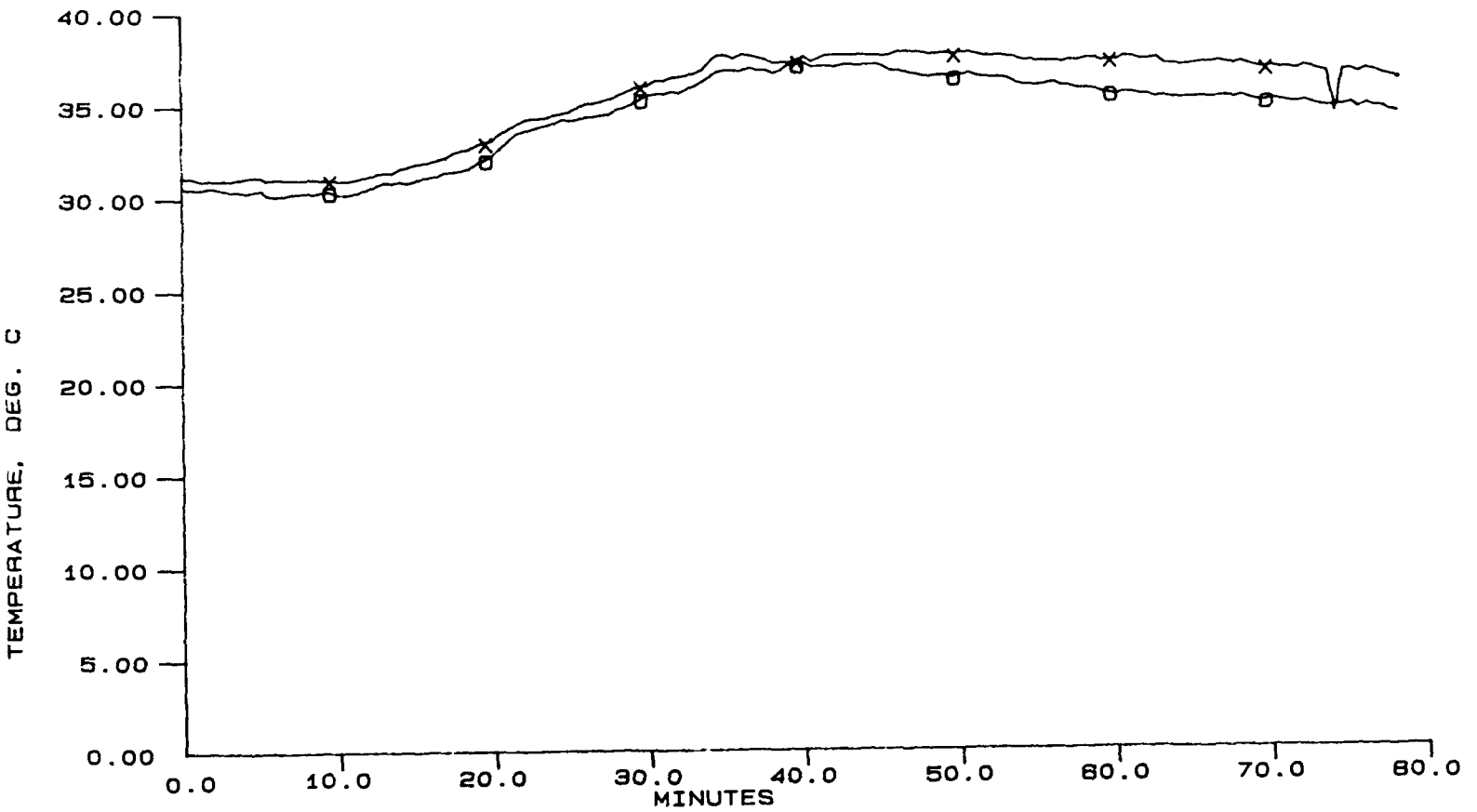


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Fig. B-69 SMOKE CURTAIN TEST W-39 LEVEL 02 CH 116 ○, 117 X, 118 +, 119 ✳

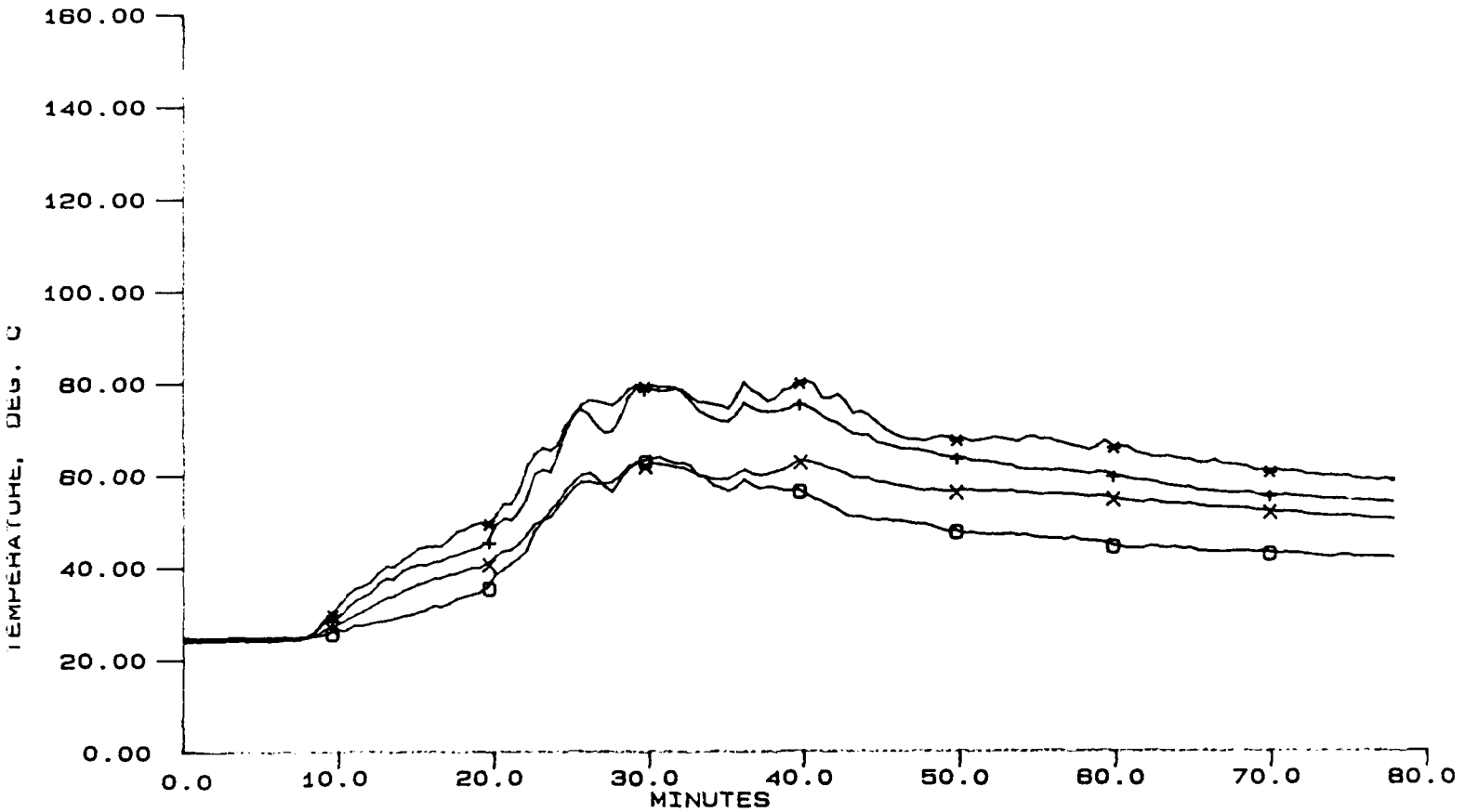
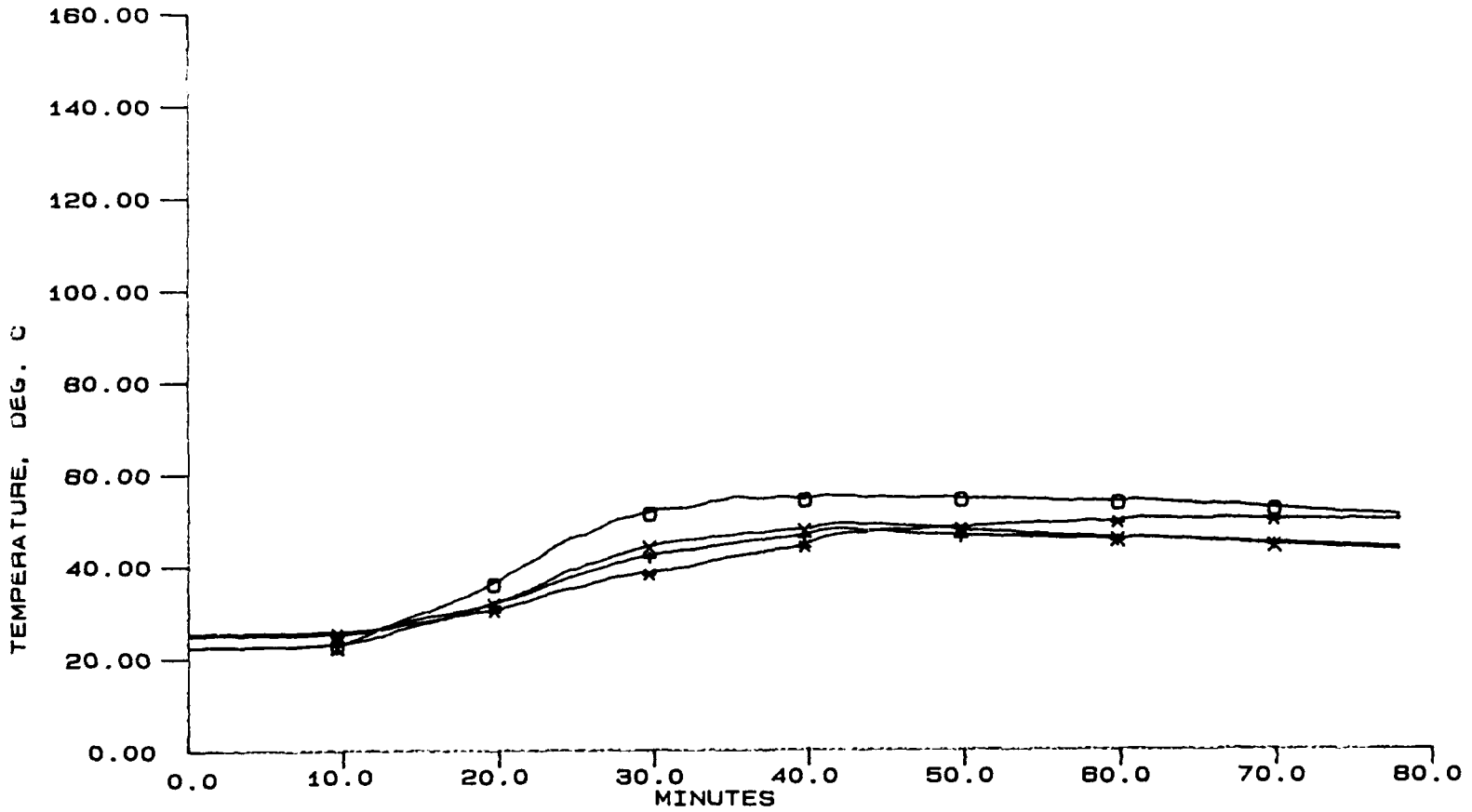


Fig. B-70 SMOKE CURTAIN TEST W-39 LEVEL 02 CH 56 ○, 57 X, 58 +, 59 ✳



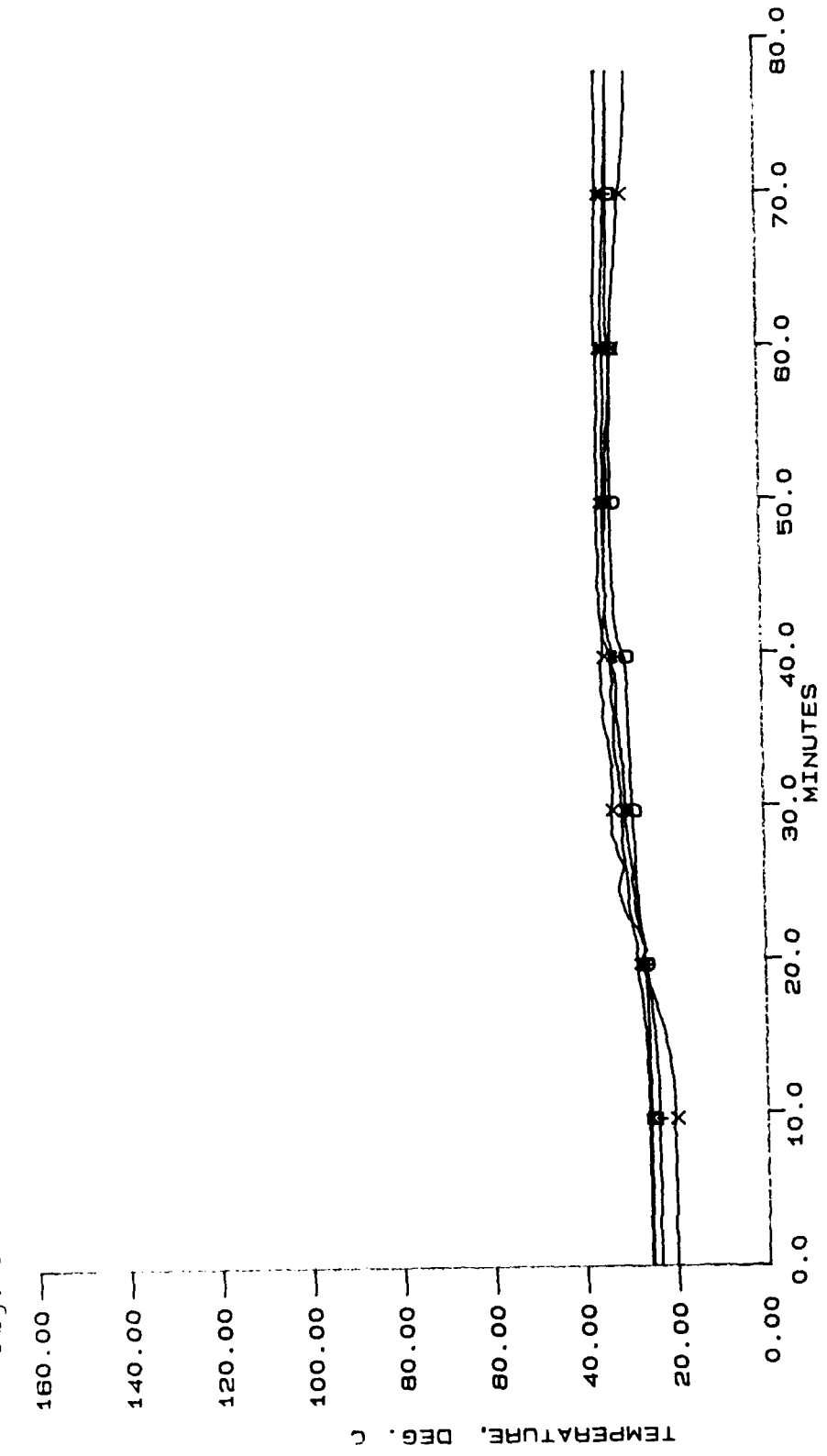
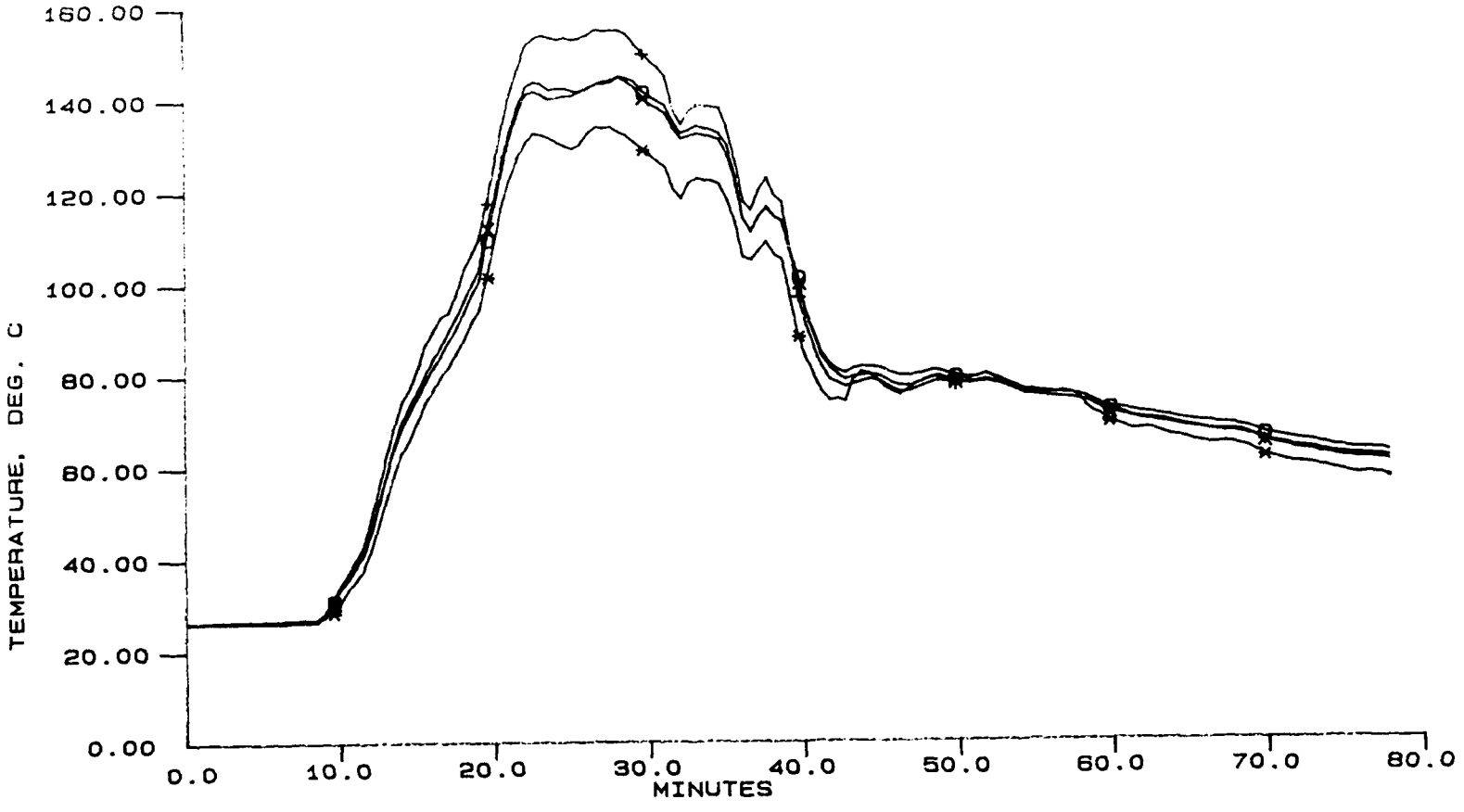


Fig. B-71 SMOKE CURTAIN TEST W-38 LEVEL 02 CH 52 O, 53 X, 54 +, 55 *
TEMPERATURE, DEG. C
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
MINUTES

Fig. B-72 SMOKE CURTAIN TEST W-39 LEVEL 02 CH 48 ○, 49 X, 50 +, 51 *



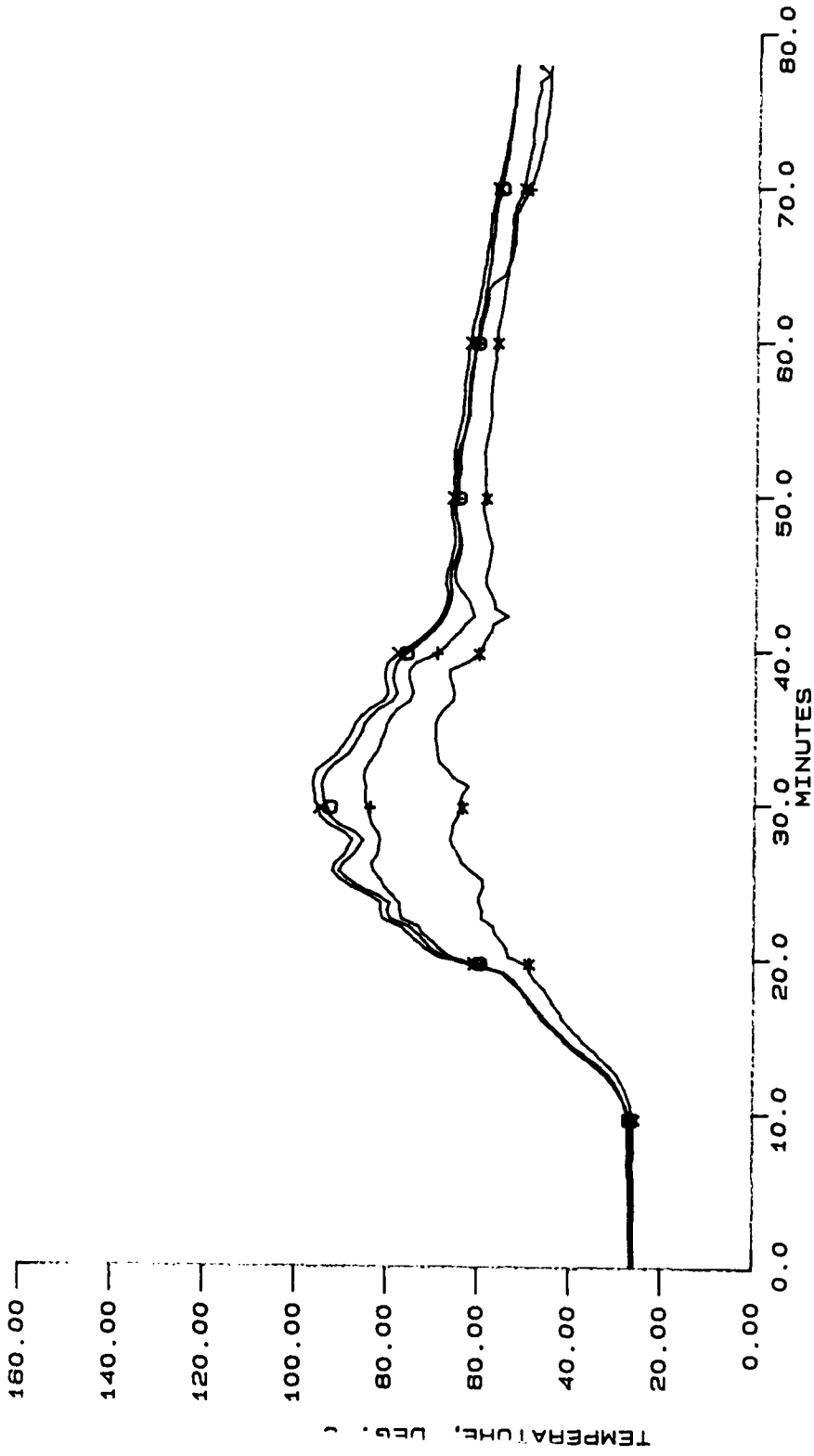


Fig. B-73 SMOKE CURTAIN TEST W-39 LEVEL 02 CH 44 ○, 45 X, 48 +, 47 ✳
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
MINUTES
TEMPERATURE, DEG. C

Fig. B-74 SMOKE CURTAIN TEST W-39 LEVEL 01 CH 72 ○, 73 X, 74 +, 75 ✳

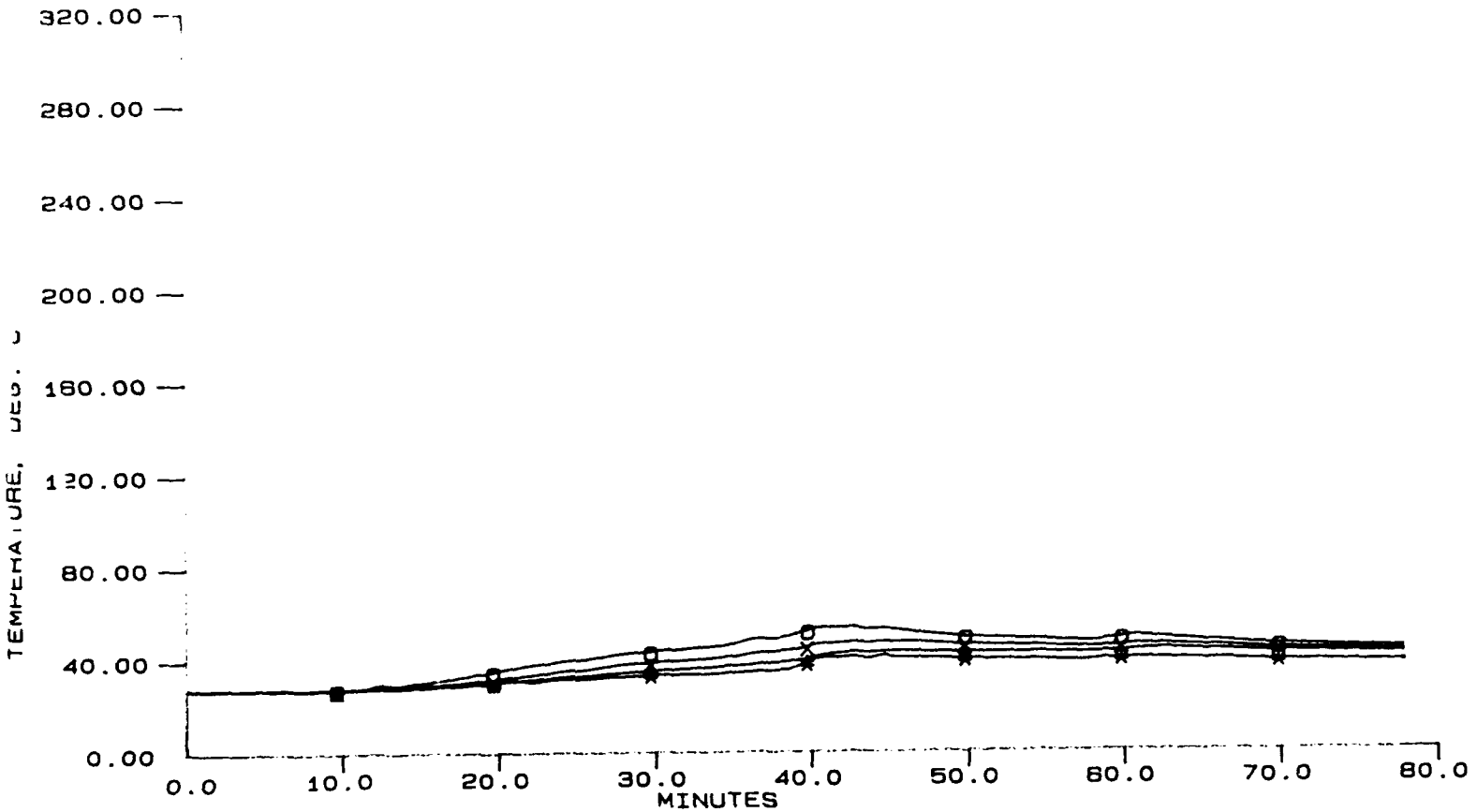


Fig. B-75 SMOKE CURTAIN TEST W-39 LEVEL 01 CH 64 ○, 65 X, 66 +, 67 ✳

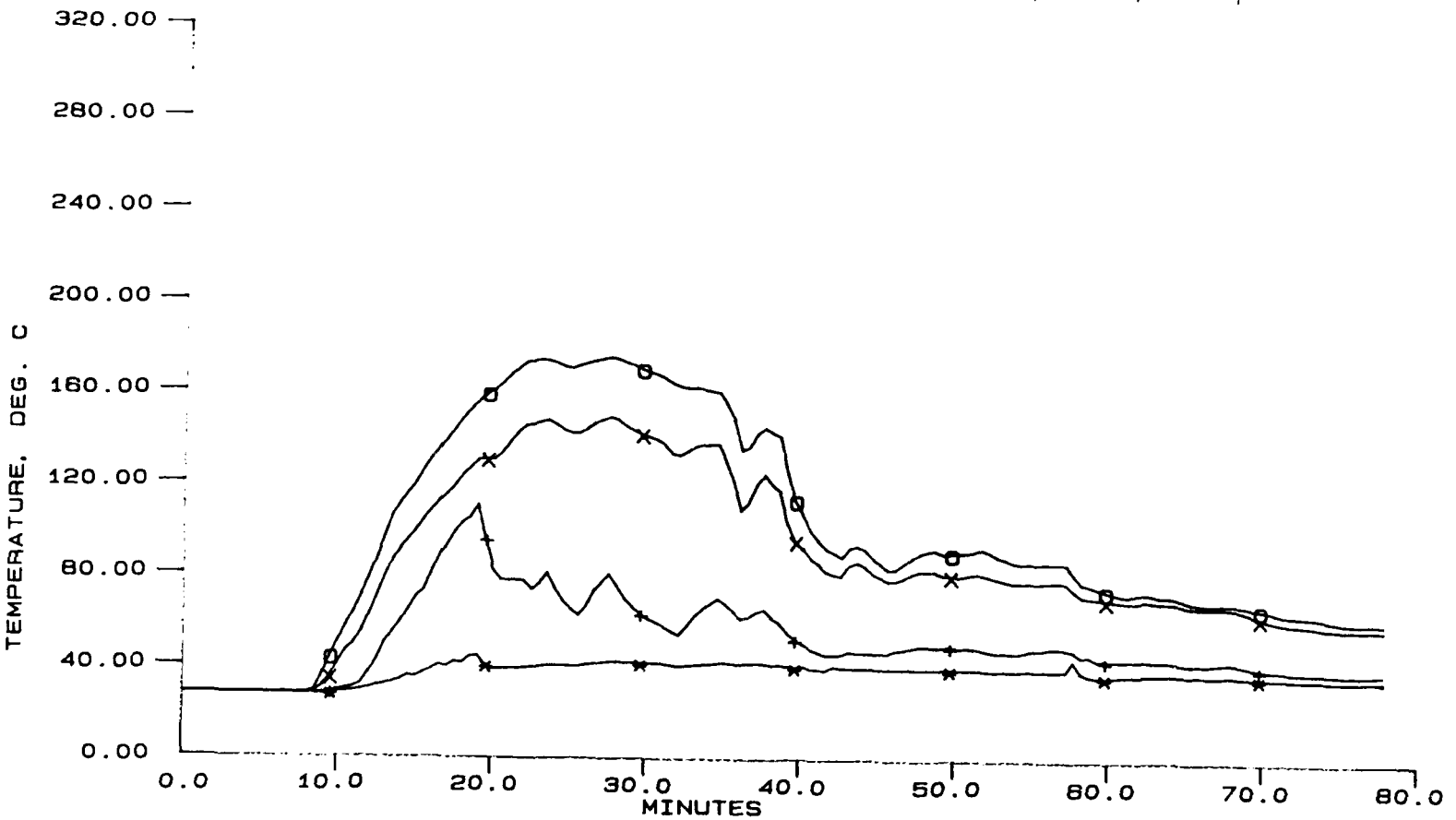


Fig. B-76 SMOKE CURTAIN TEST W-38 LEVEL 01 CH 60 ○, 61 X, 62 +, 83 ✳

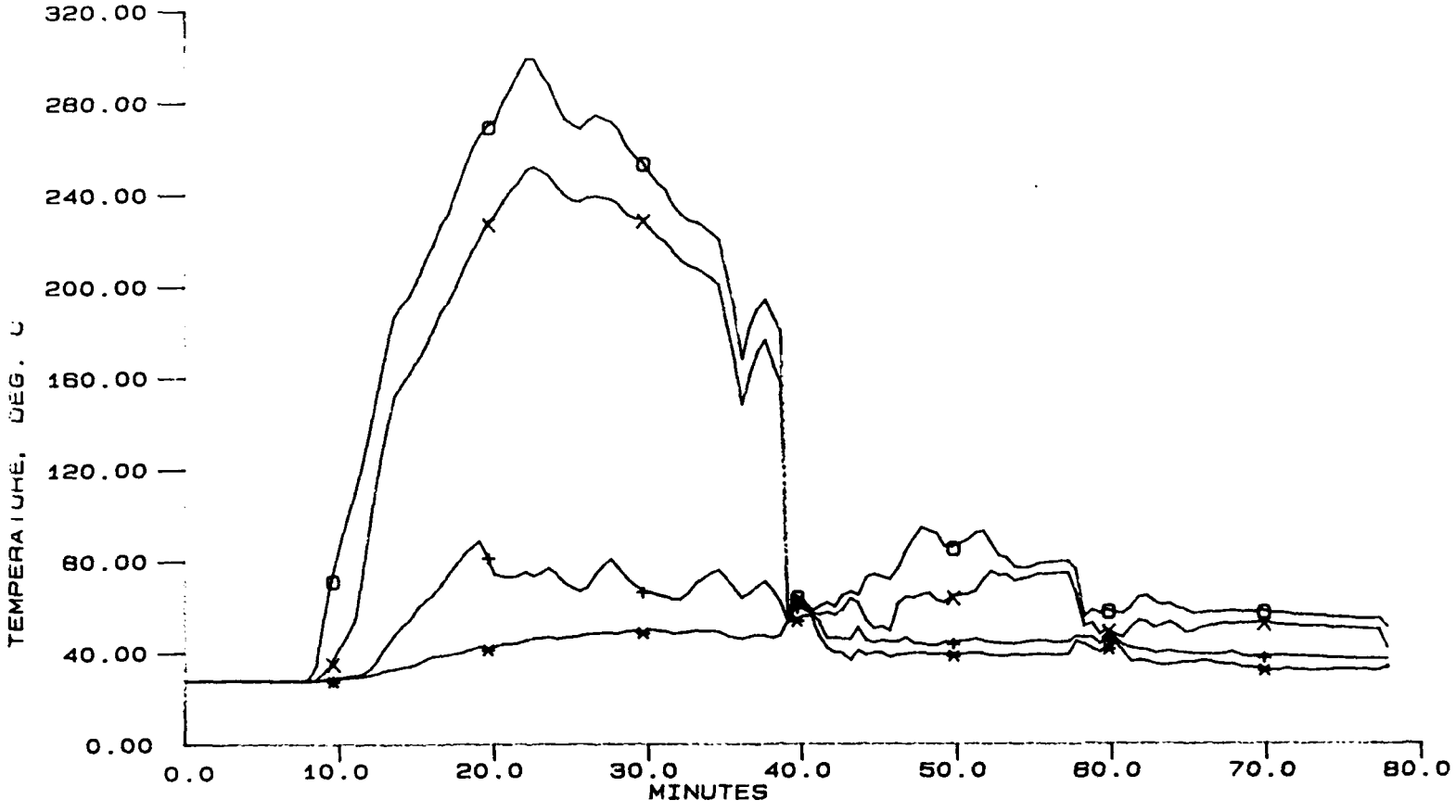


Fig. B-77 SMOKE CURTAIN TEST W-39 LEVEL 01 CH 68 ○, 69 X, 70 +, 71 ✳

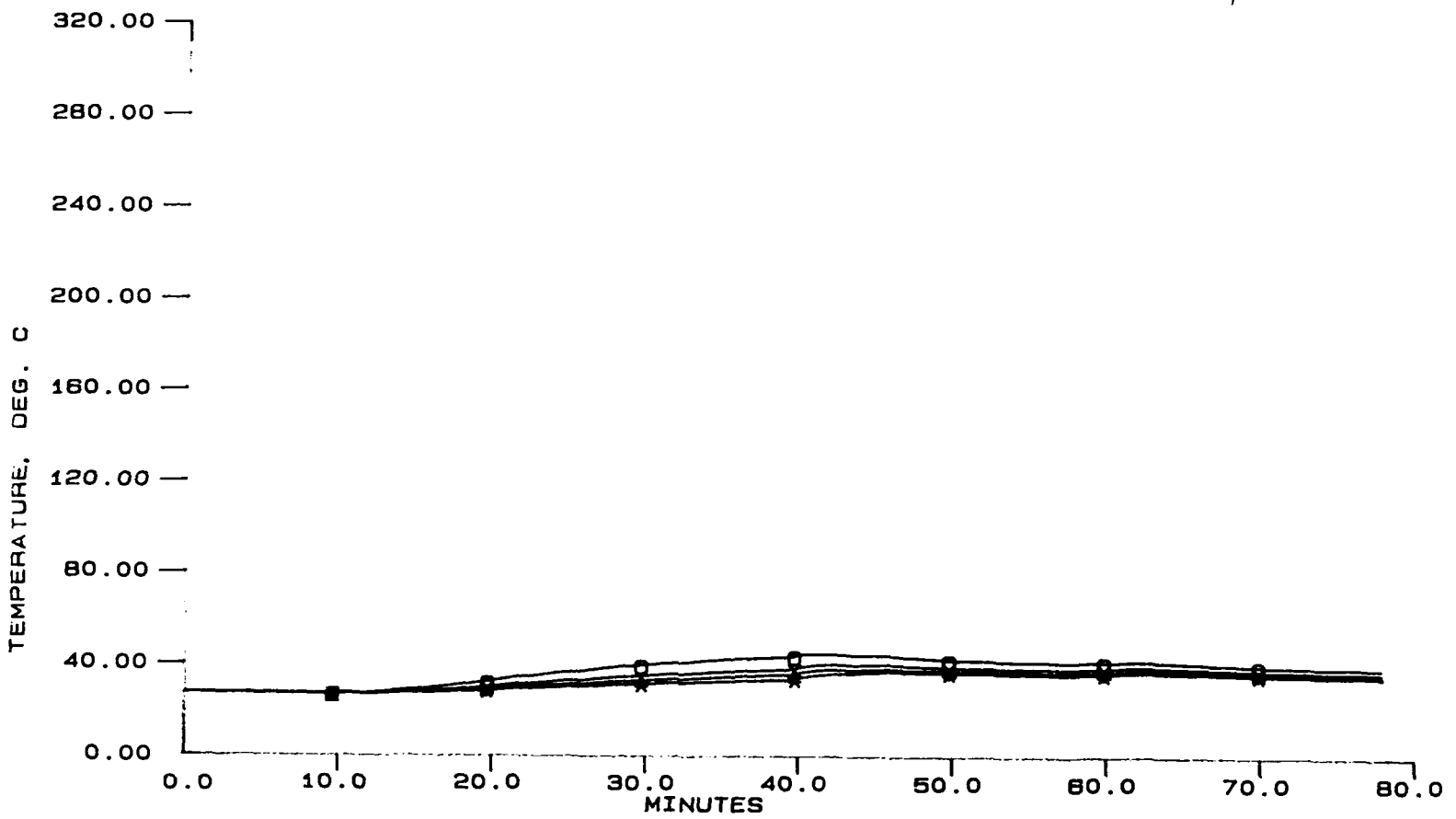


Fig. B-78 SMOKE CURTAIN TEST W-39 LEVEL 01 CH 112 O, 113 X, 114 +, 115 ✳

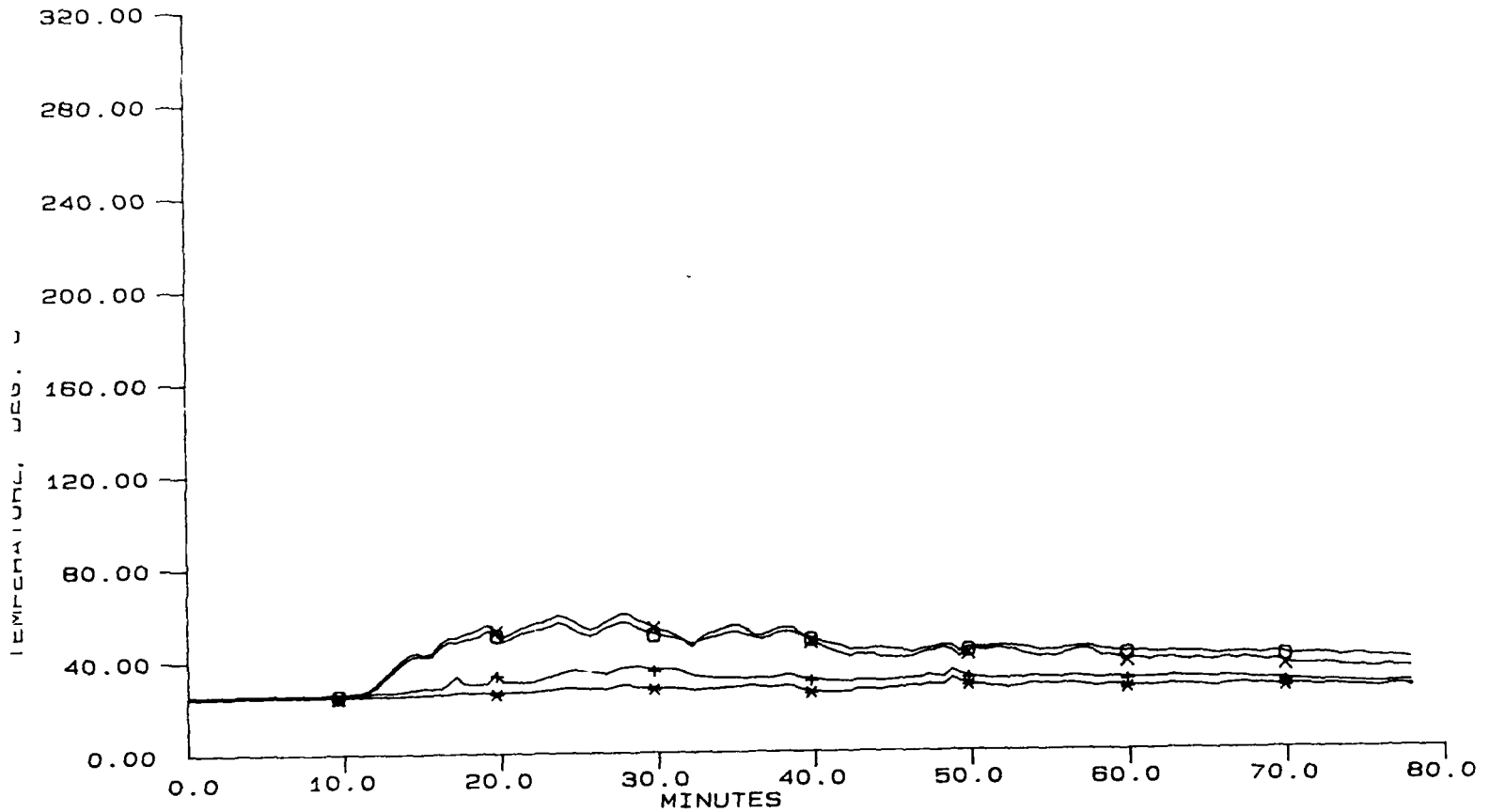


Fig. B-79 SMOKE CURTAIN TEST W-39 LEVEL 01 CH 76 ○, 77 X, 78 +, 79 ✳

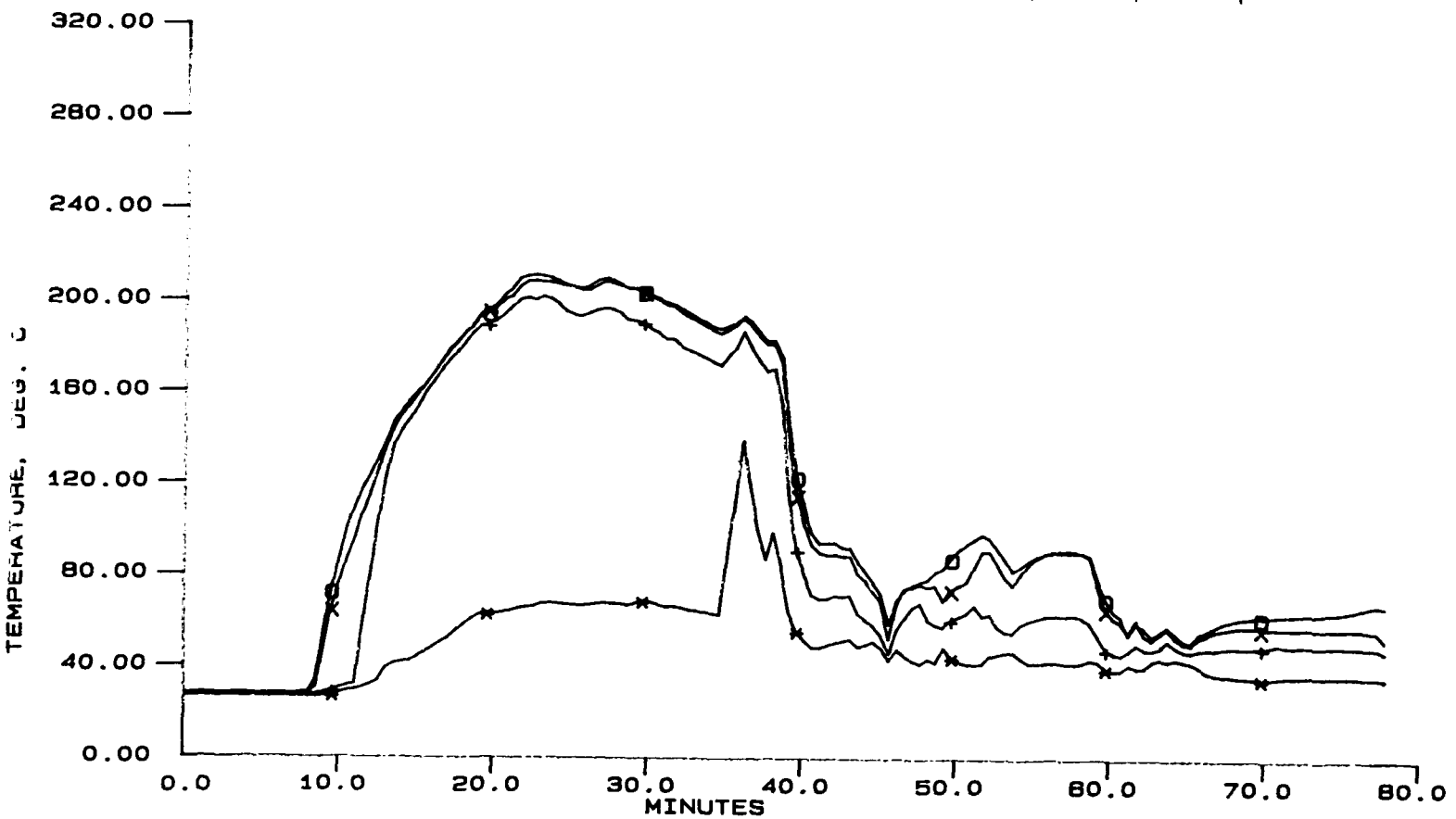


Fig. B-80 SMOKE CURTAIN TEST W-39 LEVEL 01 CH 80 ○, 81 X, 82 +, 83 ✳

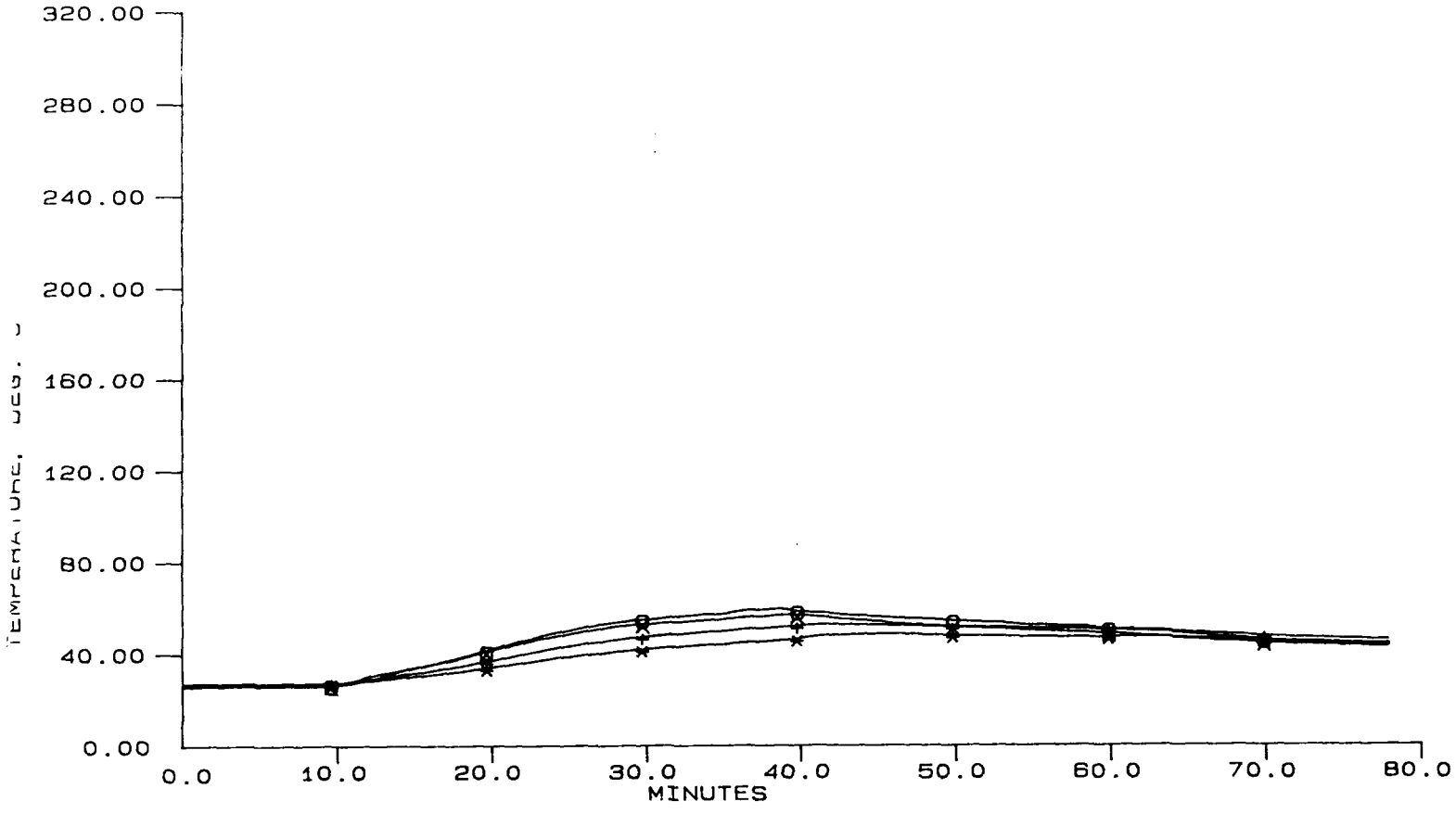


Fig. B-81 SMOKE CURTAIN TEST W-39 LEVEL 01 CH 84 O, 85 X, 86 +, 87 *

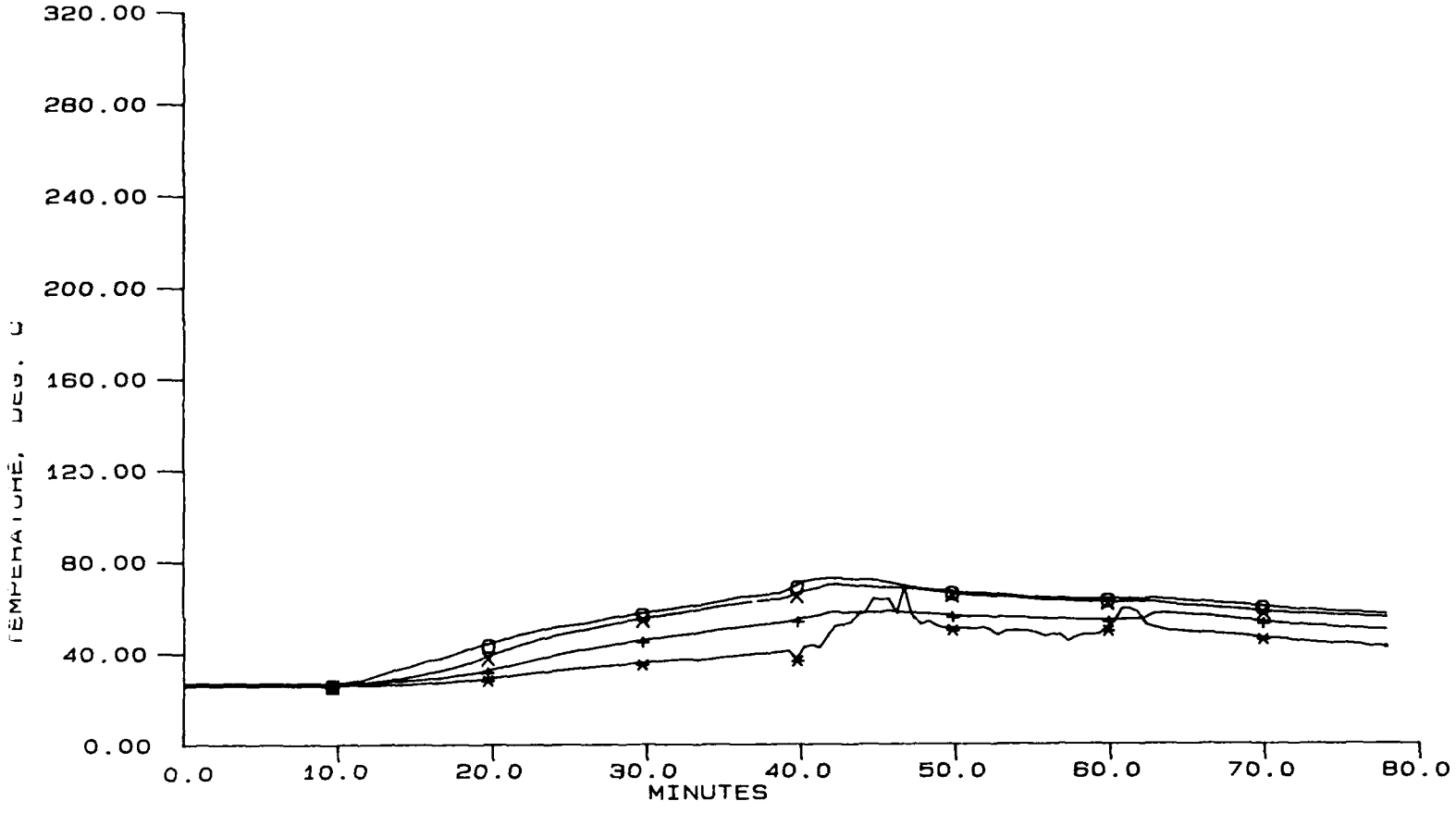


Fig. B-82 SMOKE CURTAIN TEST W-39 MAIN DECK CH 104 ○, 105 ×, 106 +, 107 ✳

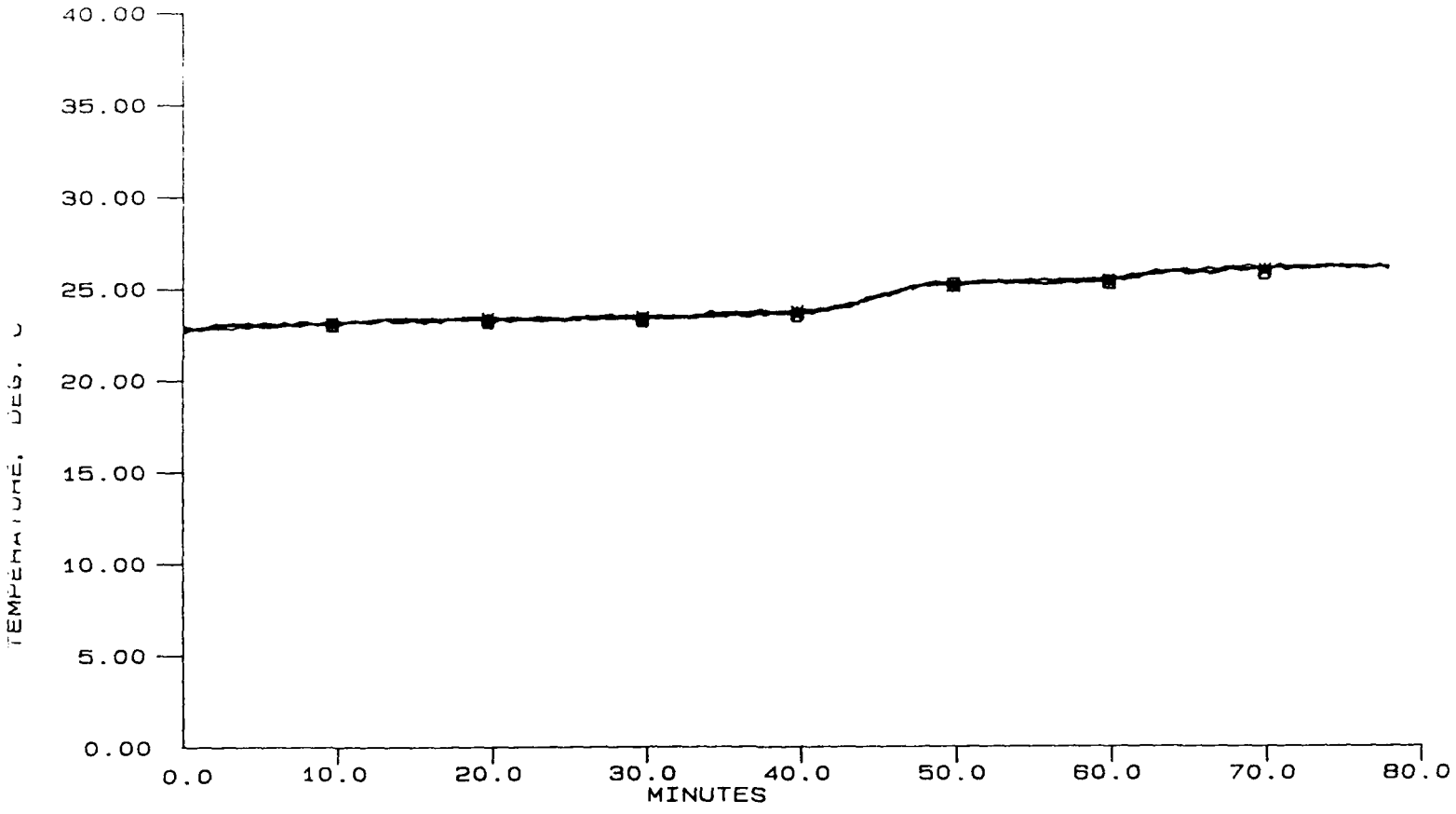


Fig. B-83 SMOKE CURTAIN TEST W-39 MAIN DECK CH 100 O, 101 X, 102 +, 103 *

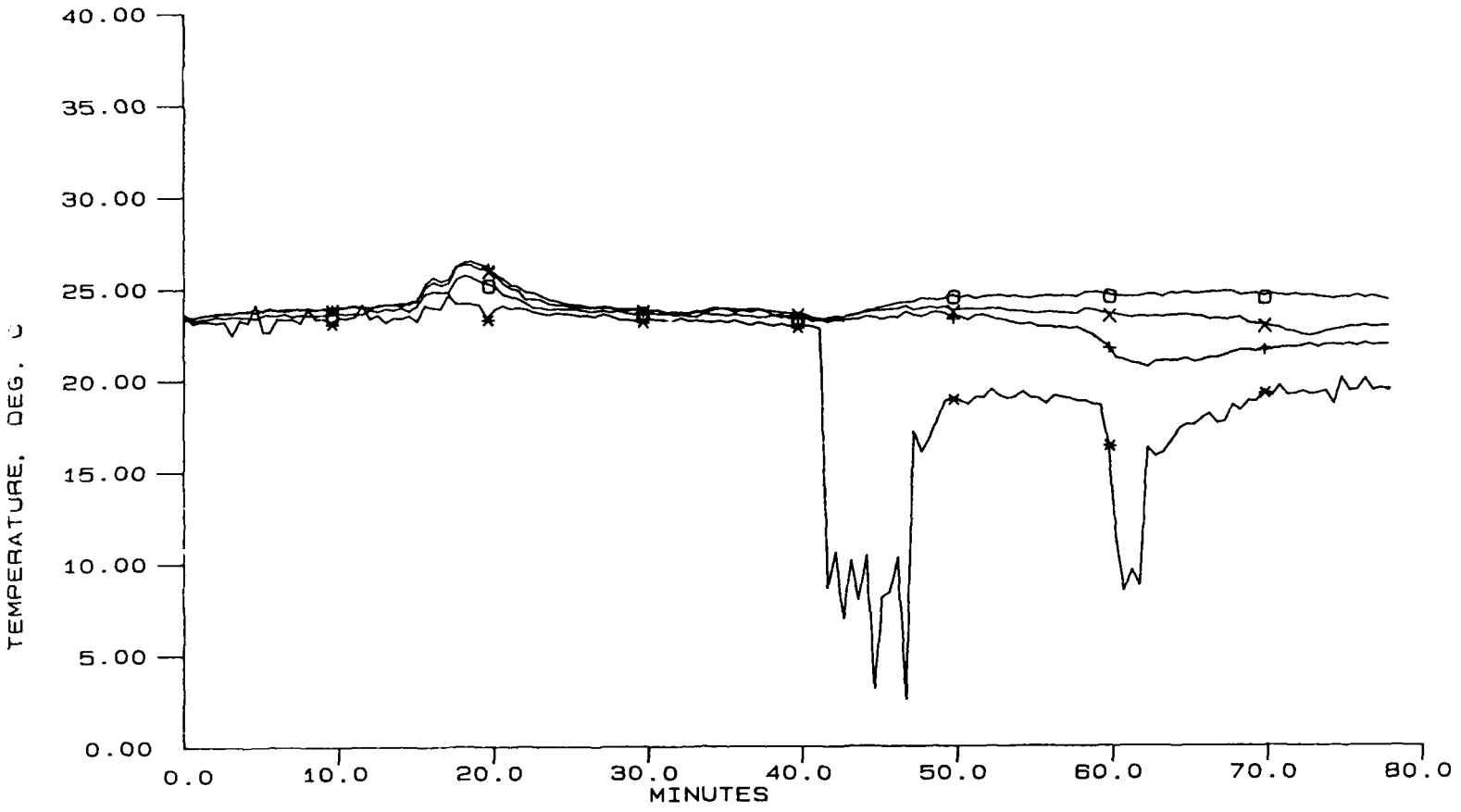


Fig. B-84 SMOKE CURTAIN TEST W-39 MAIN DECK CH 108 O, 109 X, 110 +, 111 *

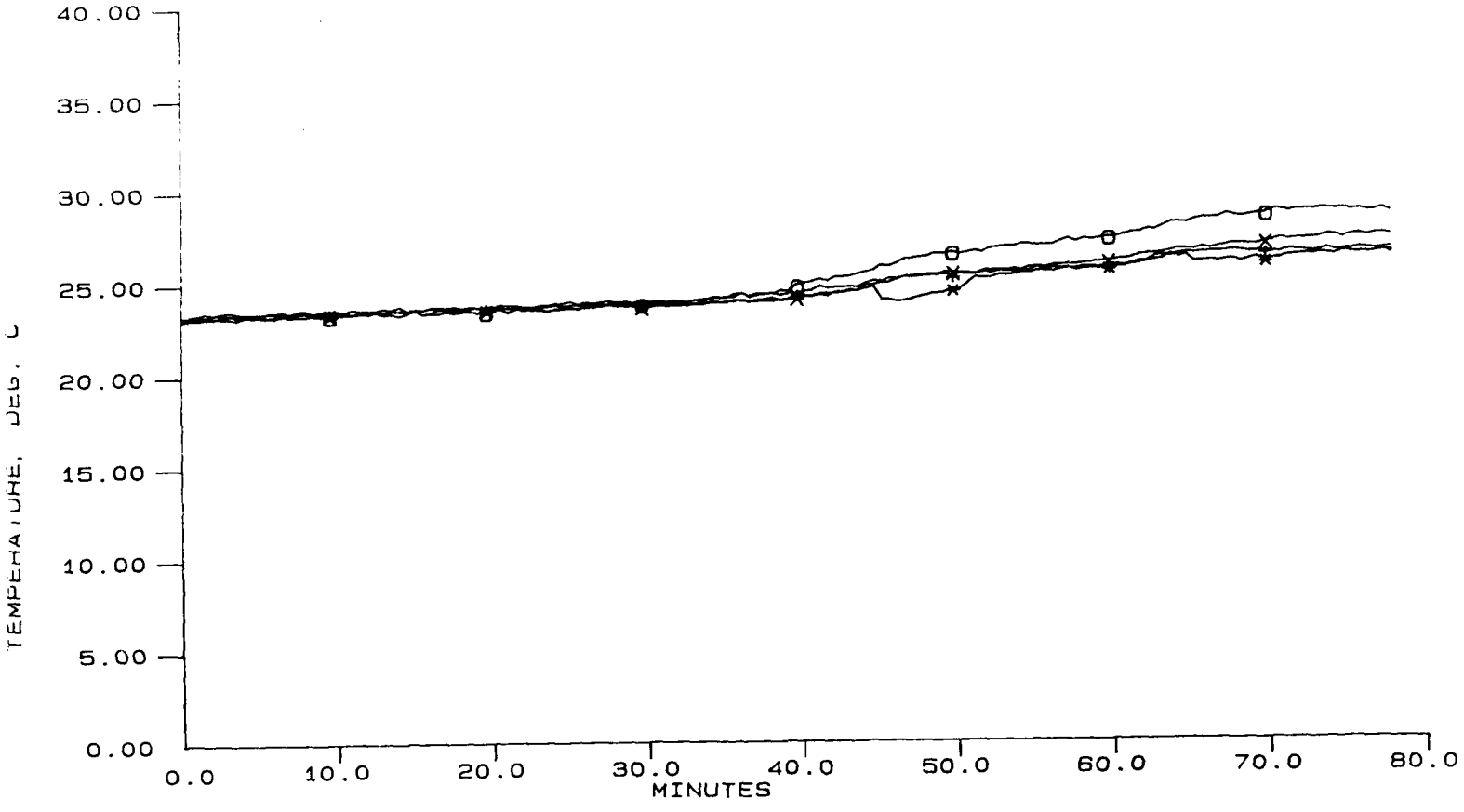


Fig. B-85 SMOKE CURTAIN TEST W-39 MAIN DECK CH 94 O, 98 X

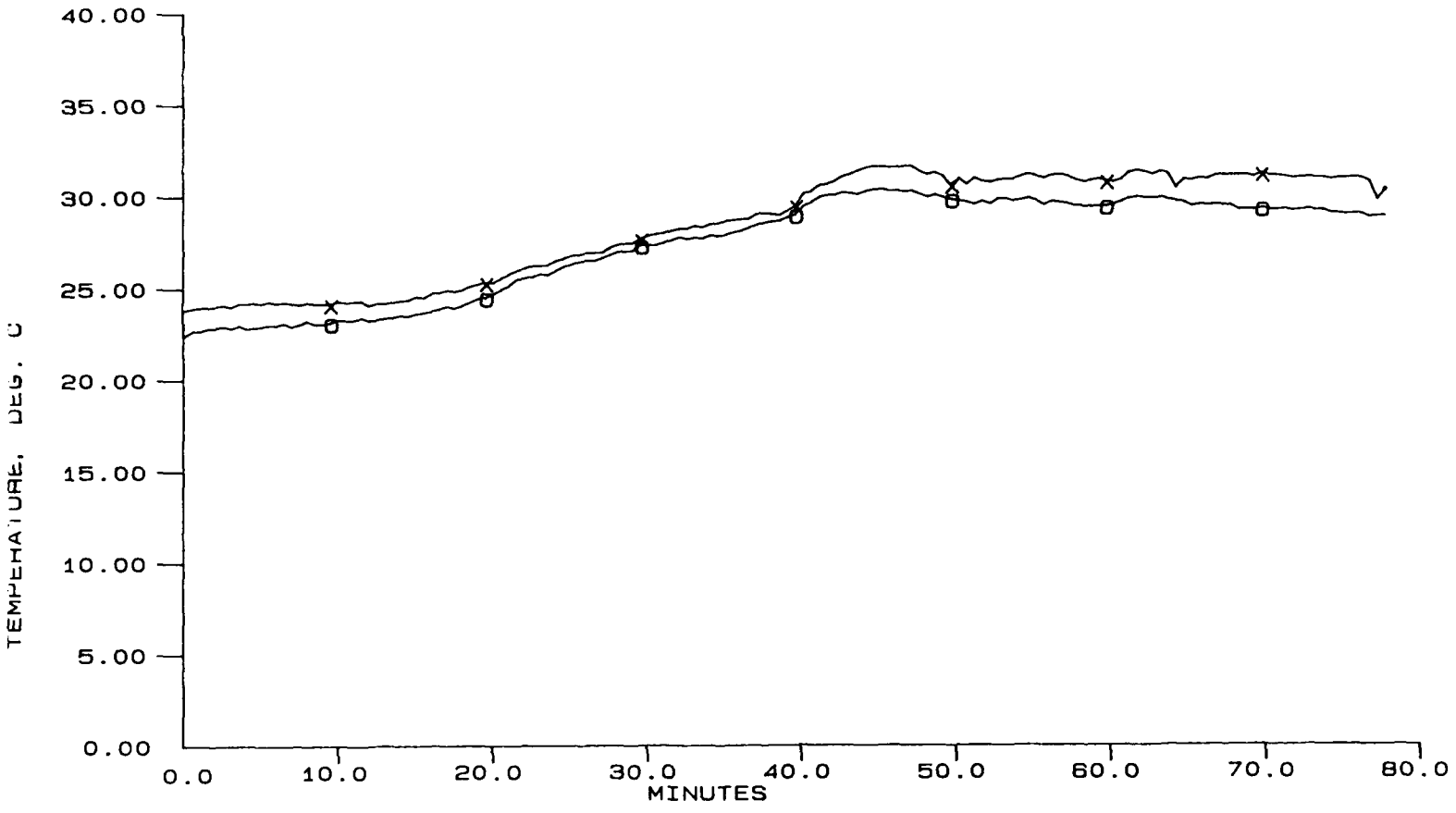


Fig. B-86 SMOKE CURTAIN TEST W-40 LEVEL 02 CH 116 O, 117 X, 118 +, 119 ✳

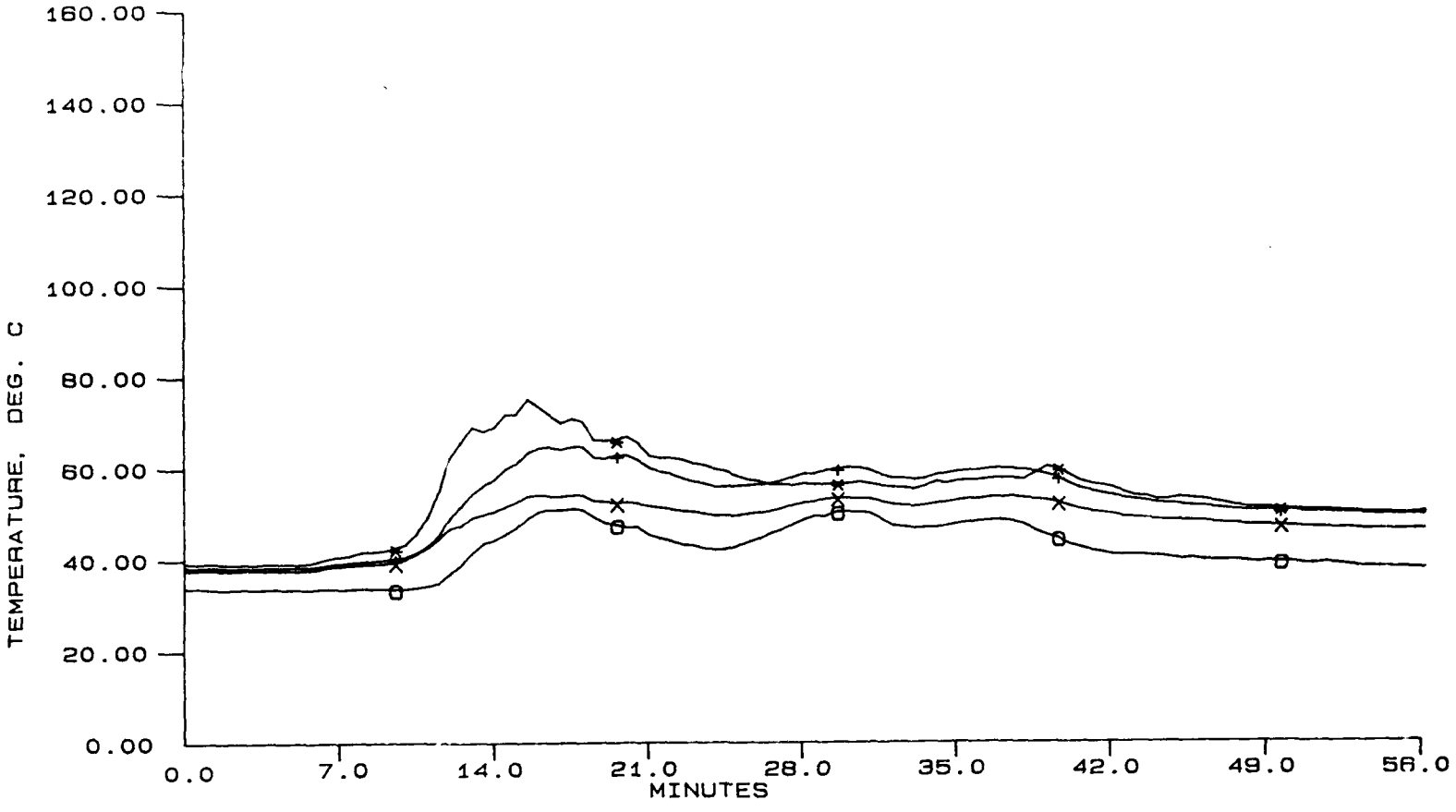


Fig. B-87 SMOKE CURTAIN TEST W-40 LEVEL 02 CH 56 O, 57 X, 58 +, 59 ✳

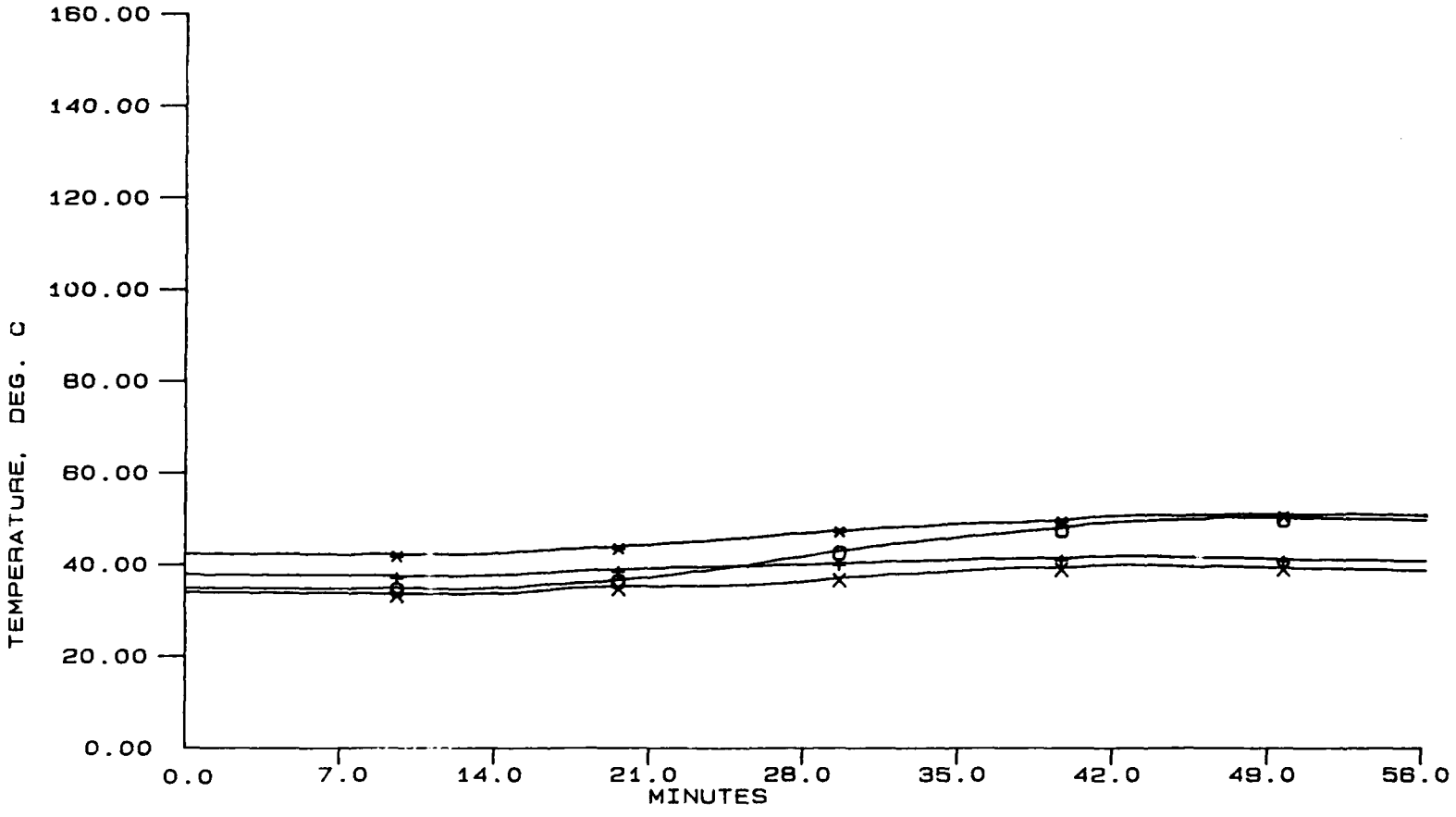


Fig. B-88 SMOKE CURTAIN TEST W-40 LEVEL 02 CH 52 ○, 53 X, 54 +, 55 ✳

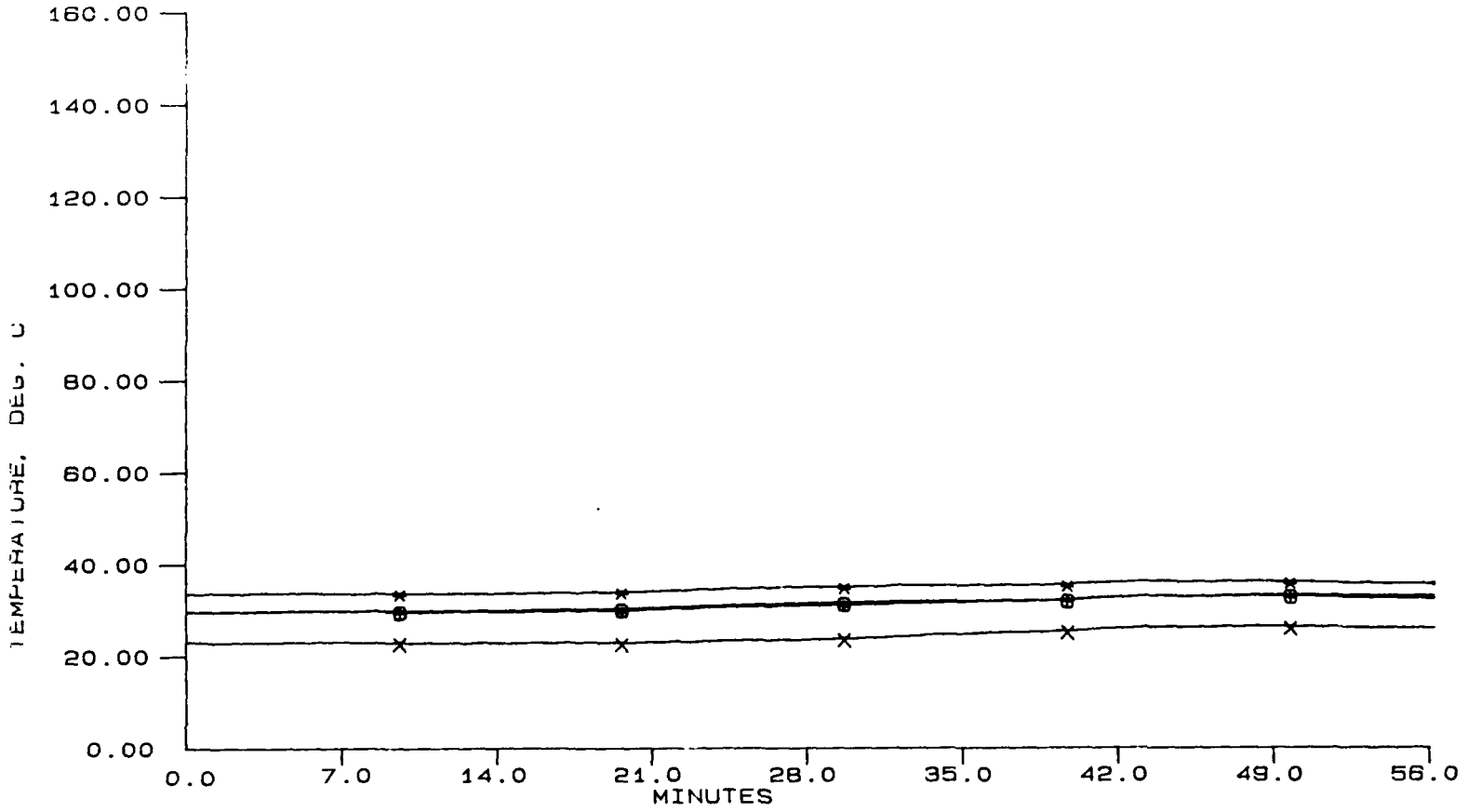


Fig. B-89 SMOKE CURTAIN TEST W-40 LEVEL 02 CH 48 ○, 49 X, 50 +, 51 ✳

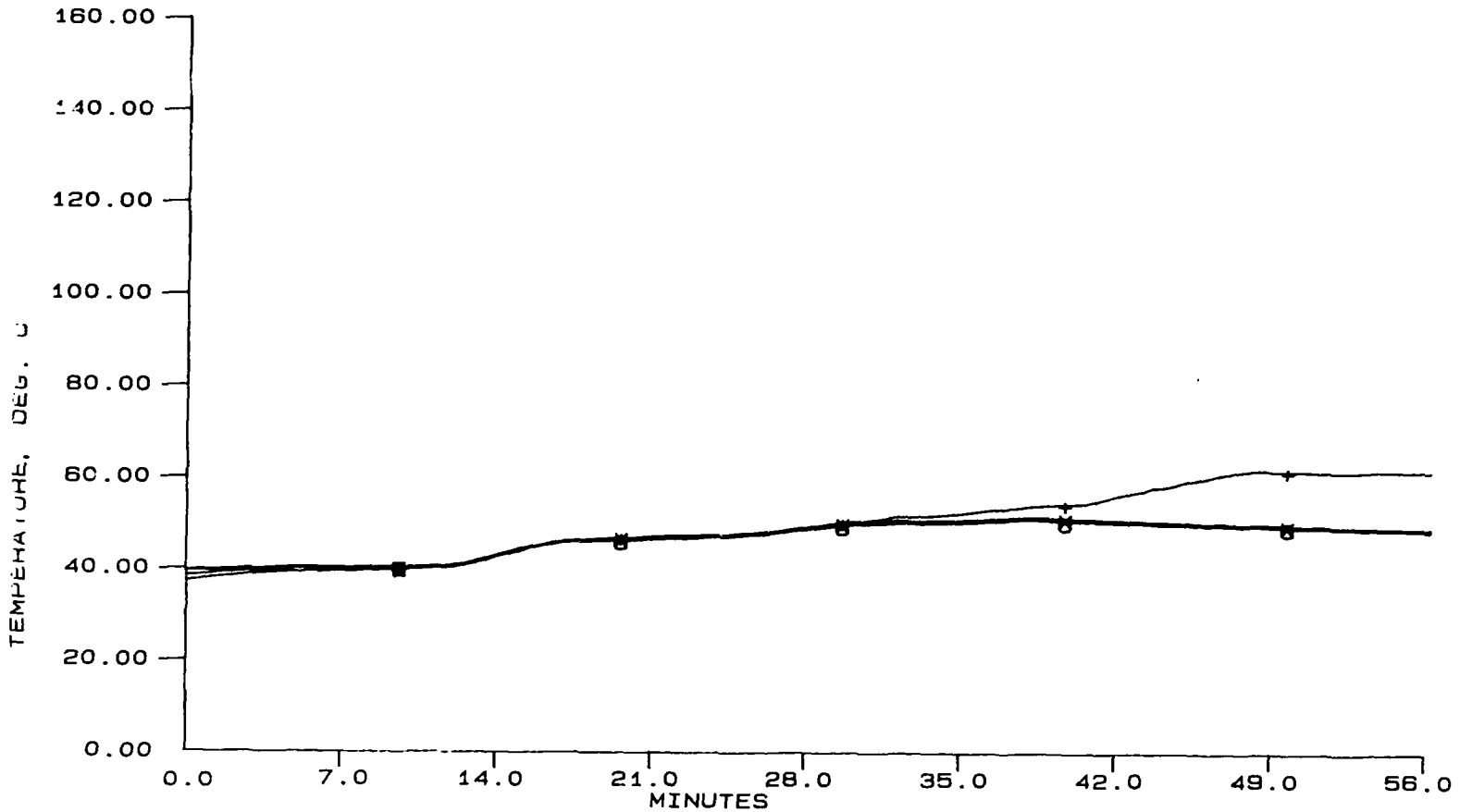


Fig. B-90 SMOKE CURTAIN TEST W-40 LEVEL 02 CH 44 O, 45 X, 46 +, 47 *

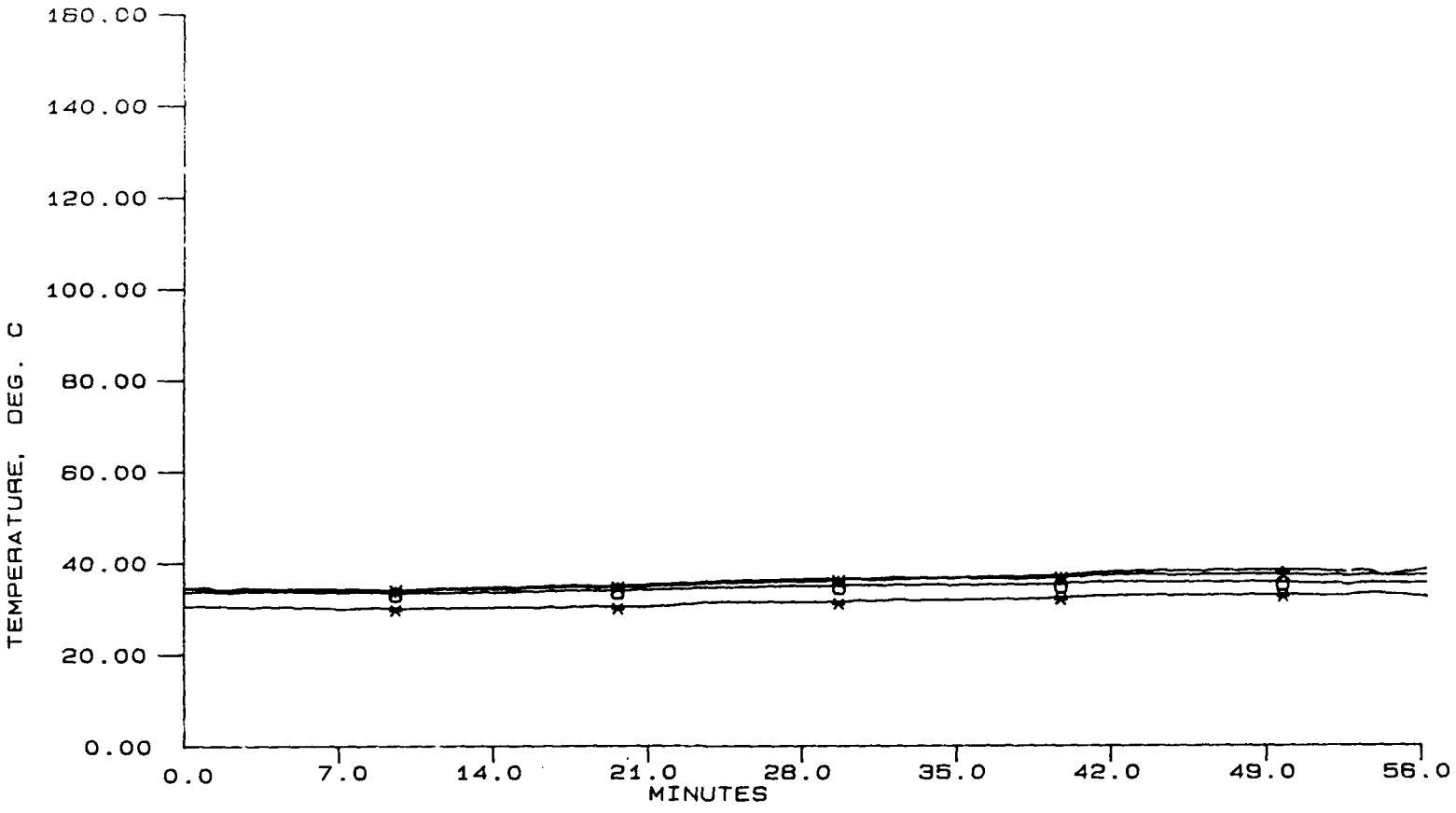


Fig. B-91 SMOKE CURTAIN TEST W-40 LEVEL 01 CH 72 ○, 73 X, 74 +, 75 ✳

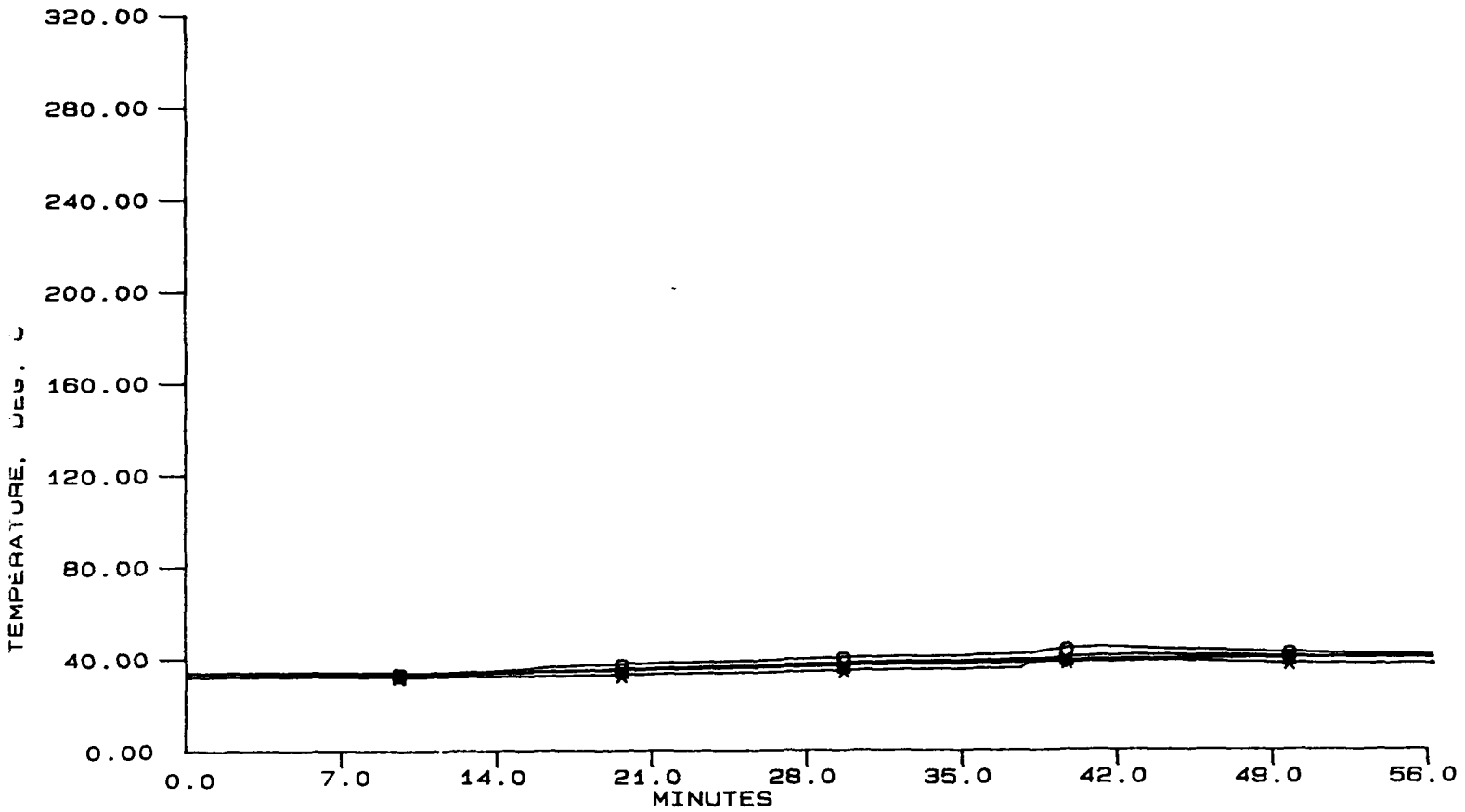


Fig. B-92 SMOKE CURTAIN TEST W-40 LEVEL 01 CH 64 O, 65 X, 66 +, 67 *

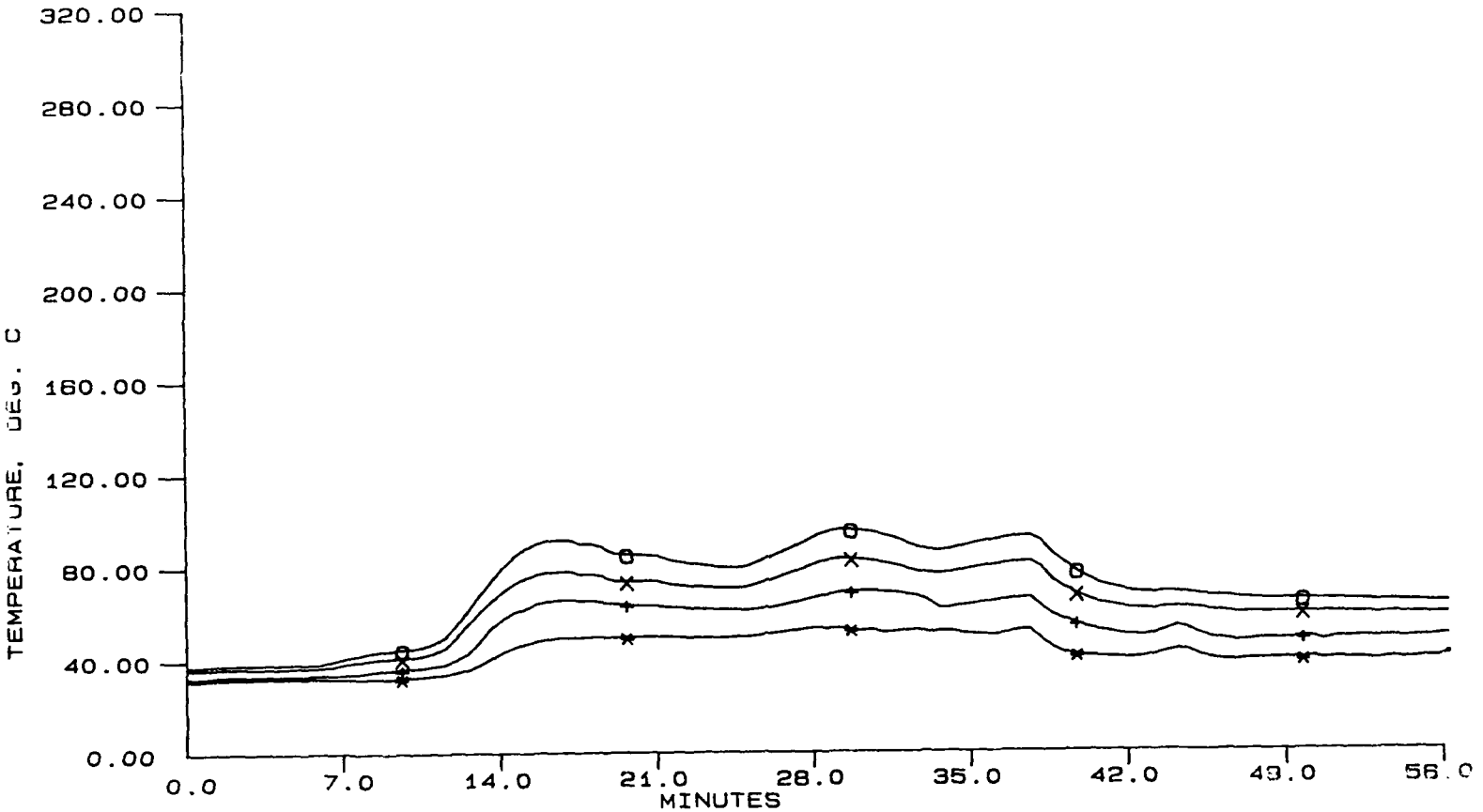


Fig. B-93 SMOKE CURTAIN TEST W-40 LEVEL 01 CH 60 O, 61 X, 62 +, 63 *

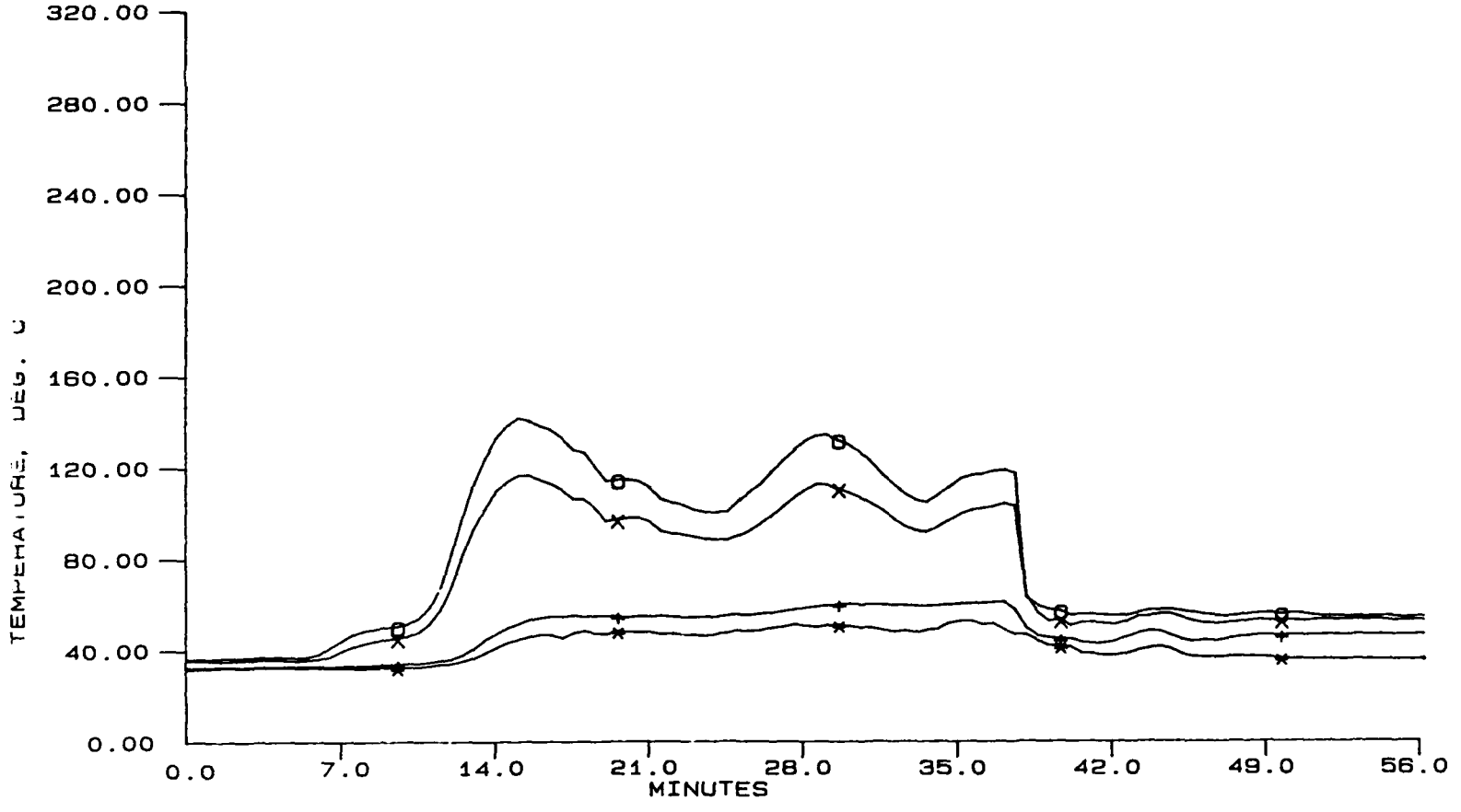


Fig. B-94 SMOKE CURTAIN TEST W-40 LEVEL 01 CH 68 O, 69 X, 70 +, 71 *

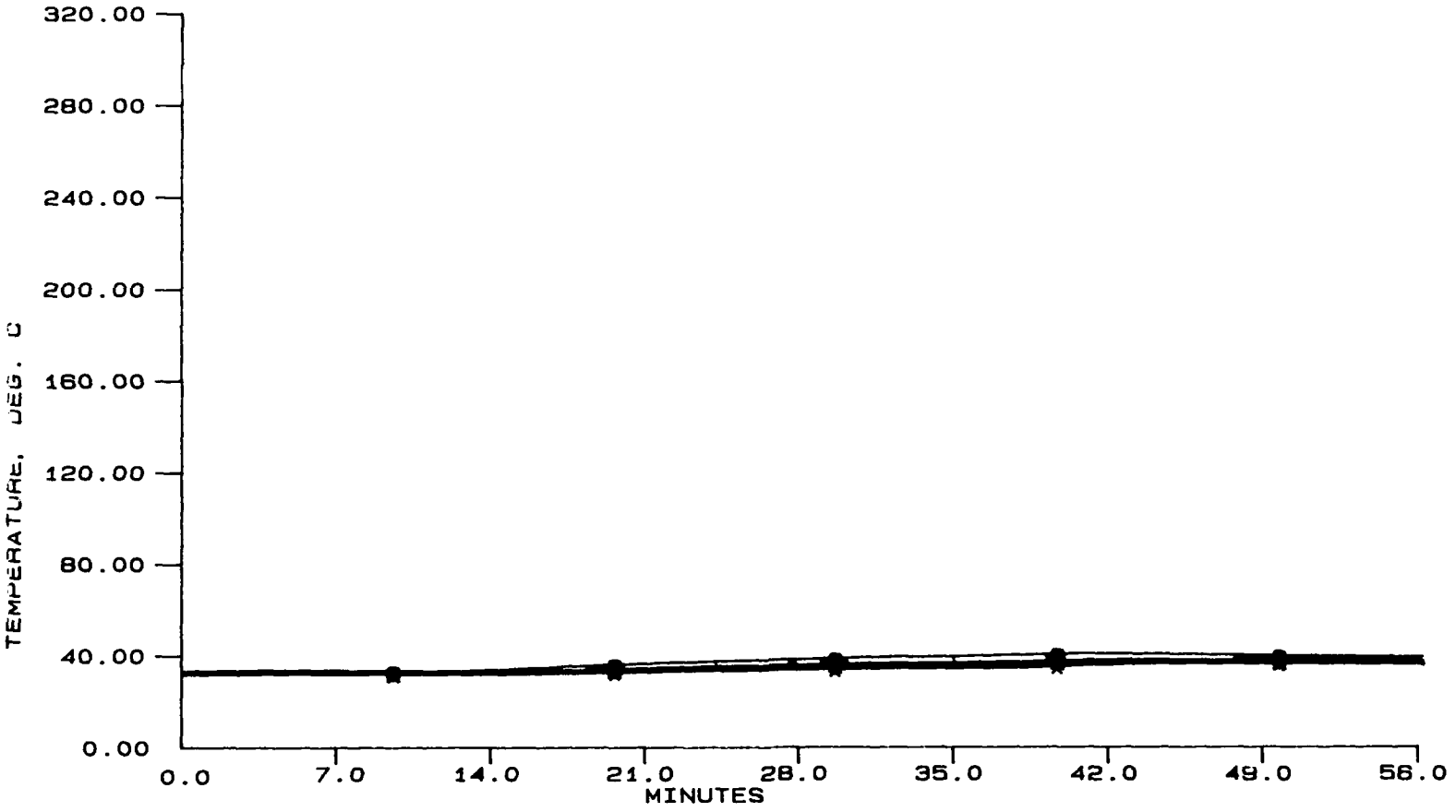


Fig. B-95 SMOKE CURTAIN TEST W-40 LEVEL 01 CH 112 O, 113 X, 114 +, 115 *

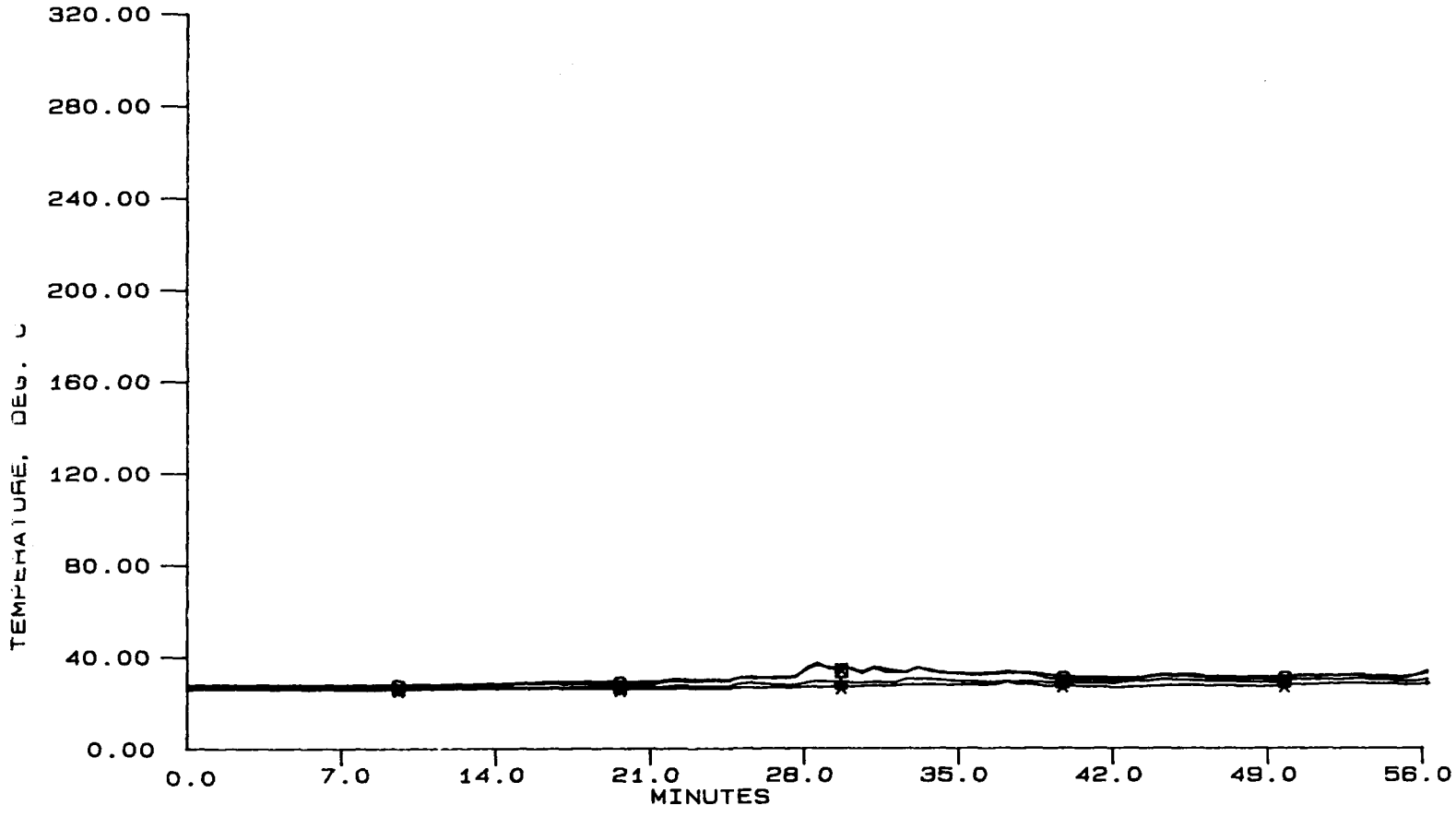


Fig. B-96 SMOKE CURTAIN TEST W-40 LEVEL 01 CH 76 O, 77 X, 78 +, 79 *

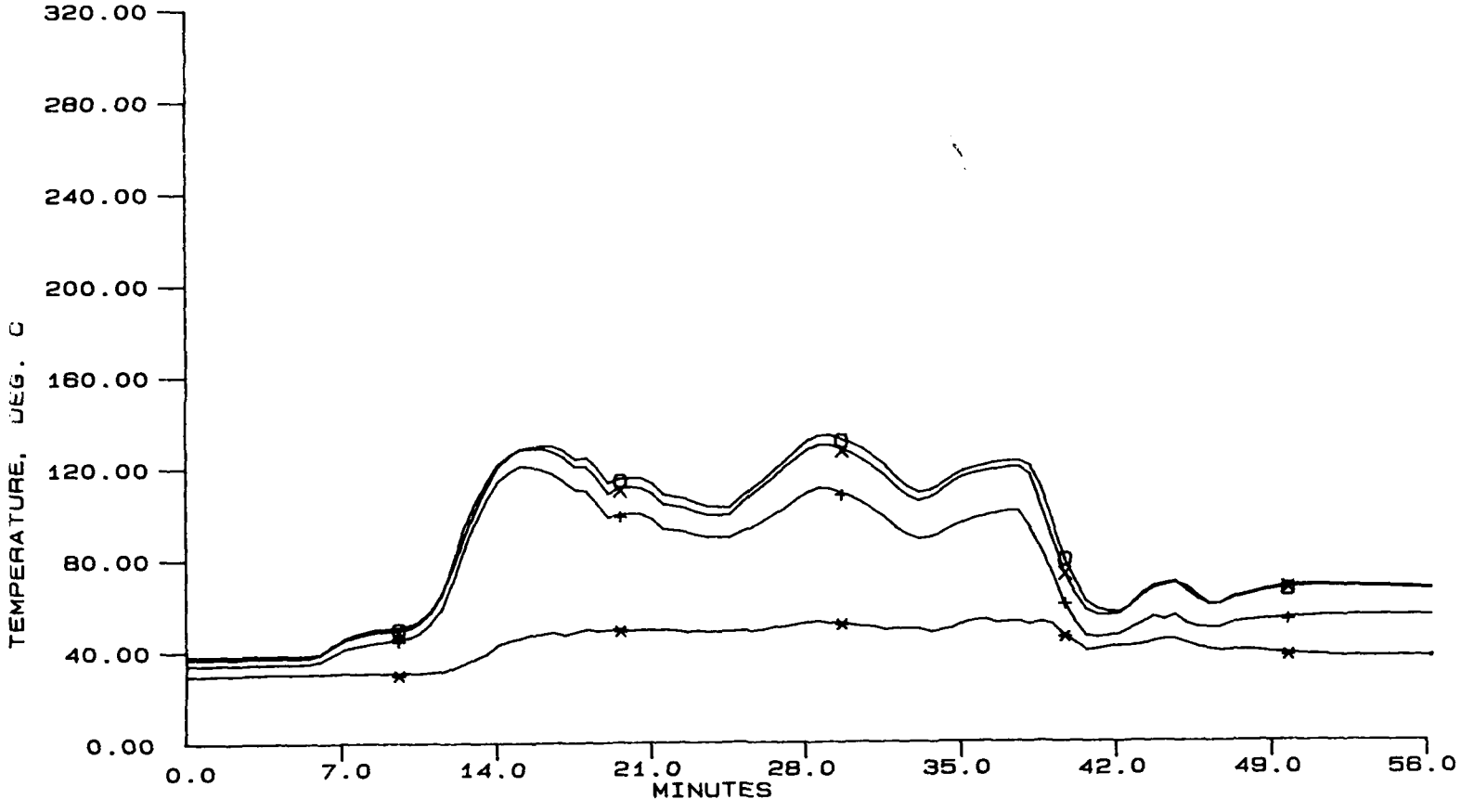
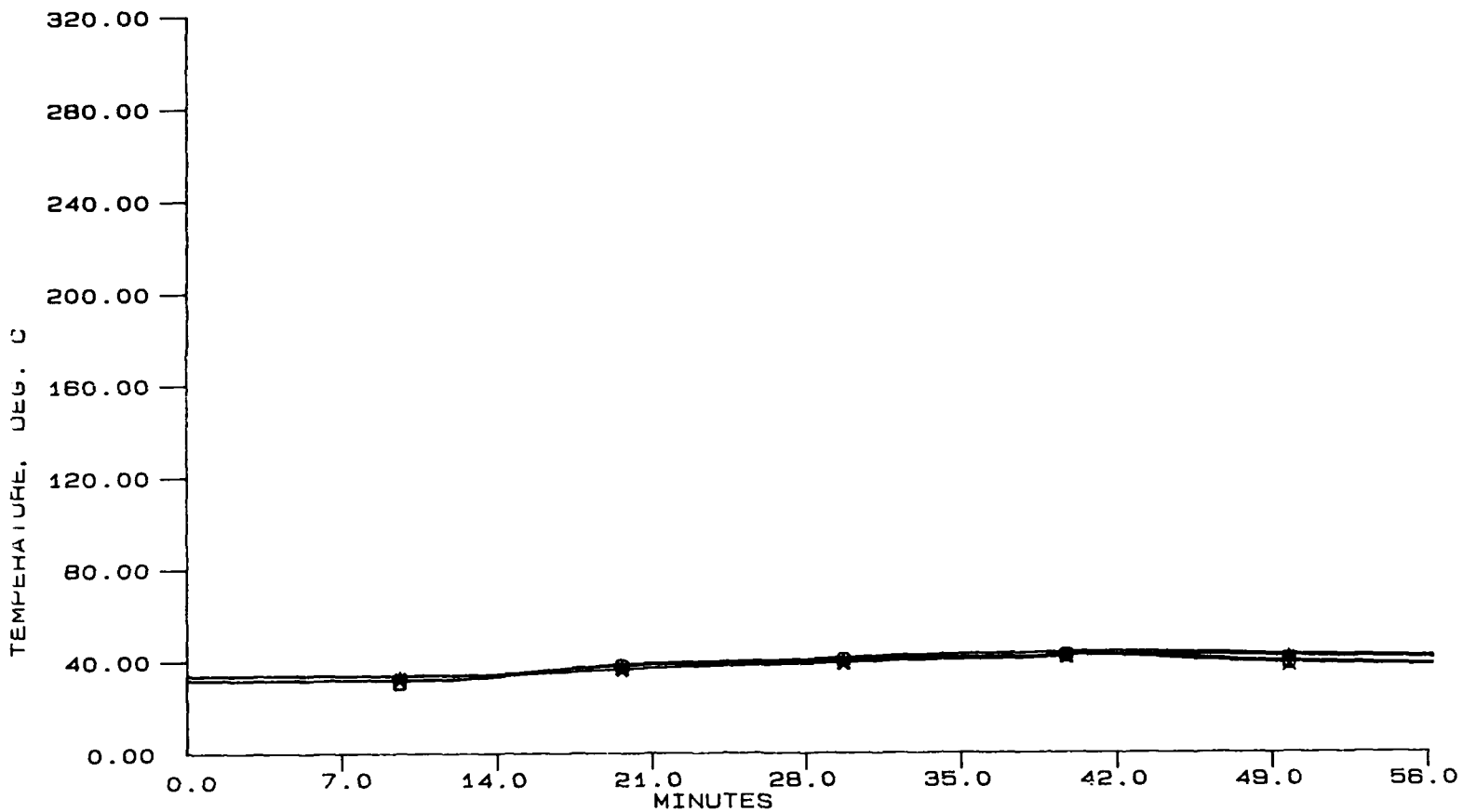


Fig. B-97 SMOKE CURTAIN TEST W-40 LEVEL 01 CH 80 O, 81 X, 82 +, 83 *



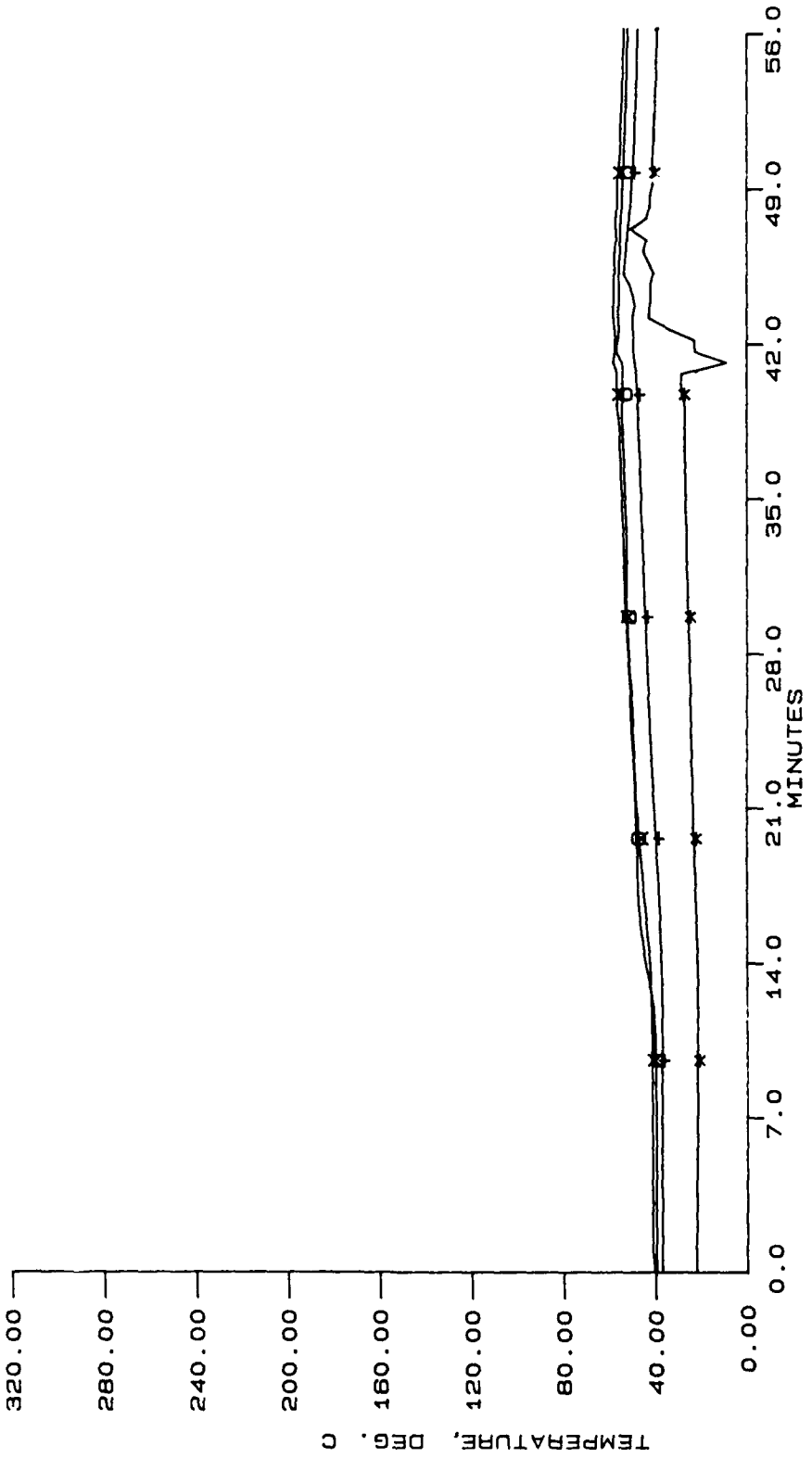
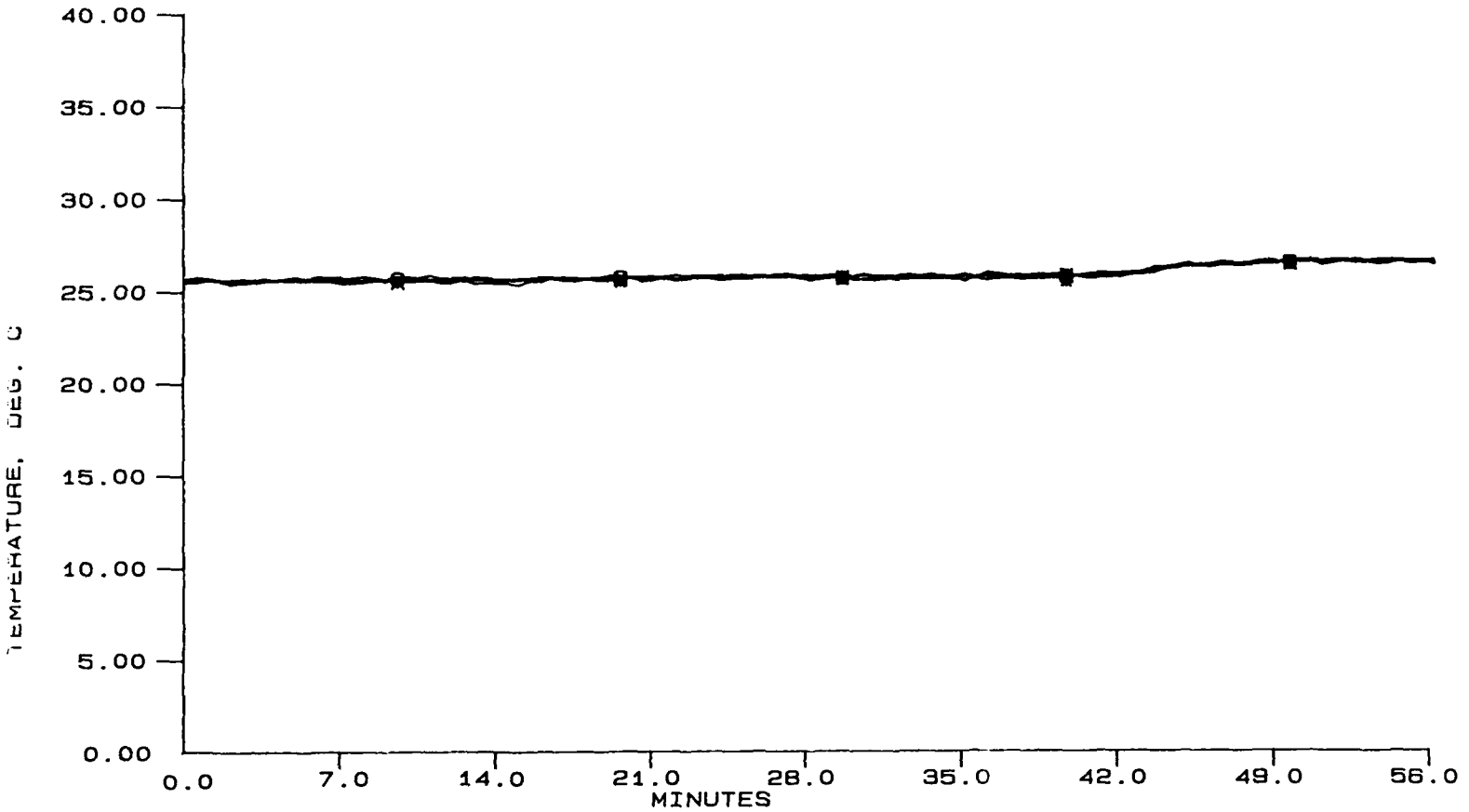


Fig. B-98 SMOKE CURTAIN TEST W-40 LEVEL 01 CH 84 O, 85 X, 86 +, 87 *
TEMPERATURE, DEG. C
320.00
280.00
240.00
200.00
160.00
120.00
80.00
40.00
0.00
0.0
7.0
14.0
21.0
28.0
35.0
42.0
49.0
56.0
MINUTES

Fig. B-99 SMOKE CURTAIN TEST W-40 MAIN DECK CH 104 O, 105 X, 106 +, 107 *



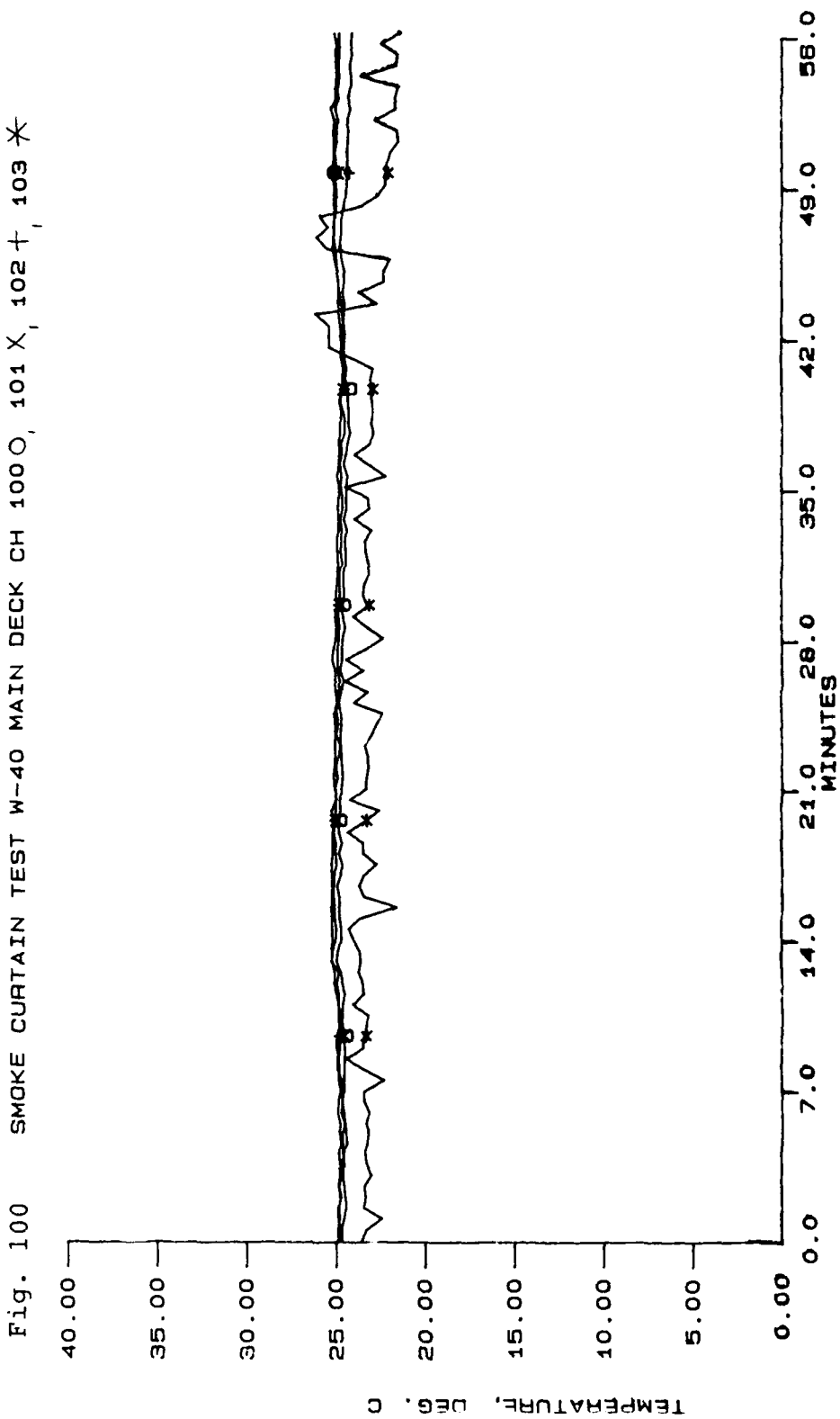

SMOKE CURTAIN TEST W-40 MAIN DECK CH 100 ○, 101 ×, 102 +, 103 ✳
TEMPERATURE, DEG. C
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.0
7.0
14.0
21.0
28.0
35.0
42.0
49.0
56.0
MINUTES

Fig. 100

Fig. B-101 SMOKE CURTAIN TEST W-40 MAIN DECK CH 108 ○, 109 ×, 110 +, 111 ✳

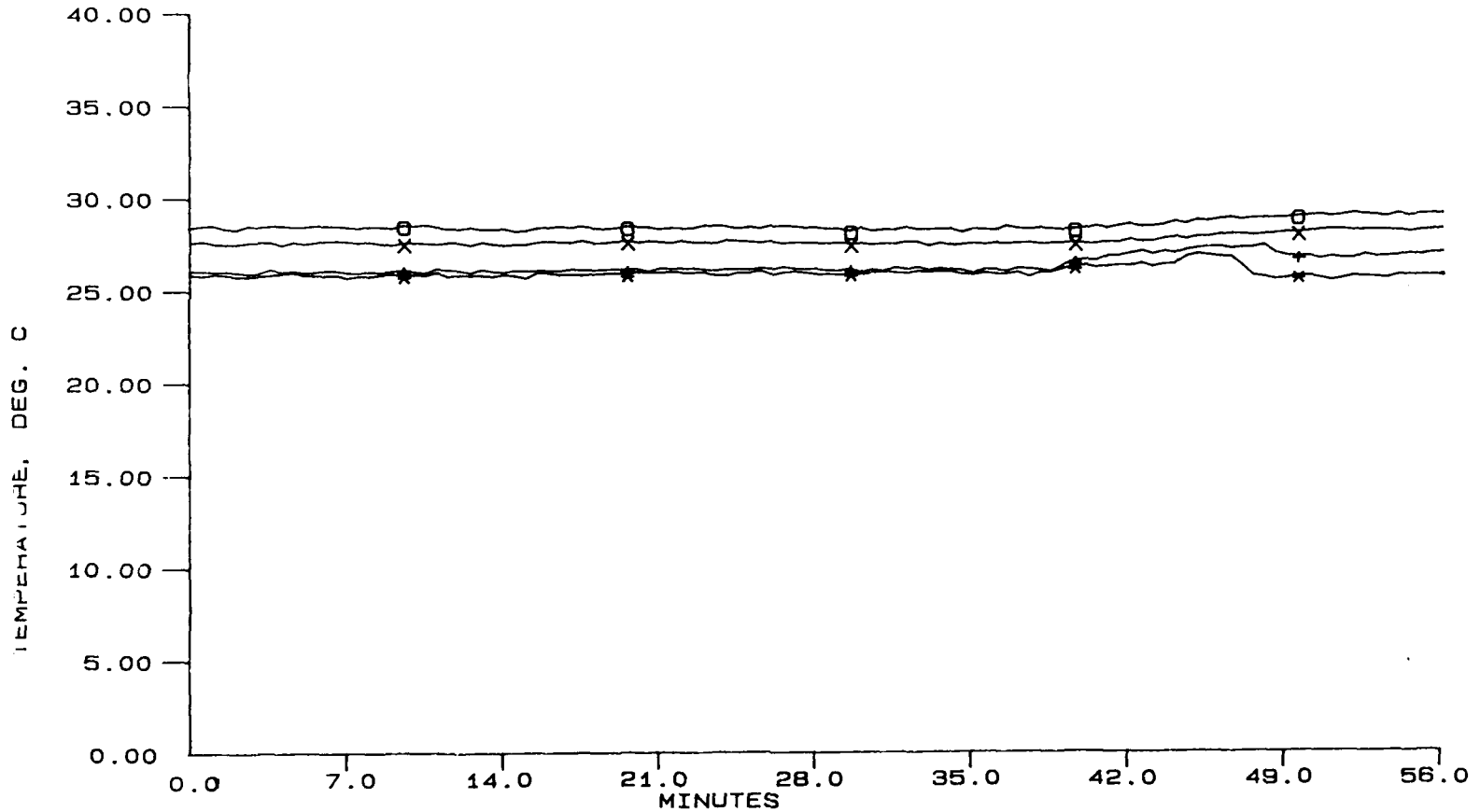
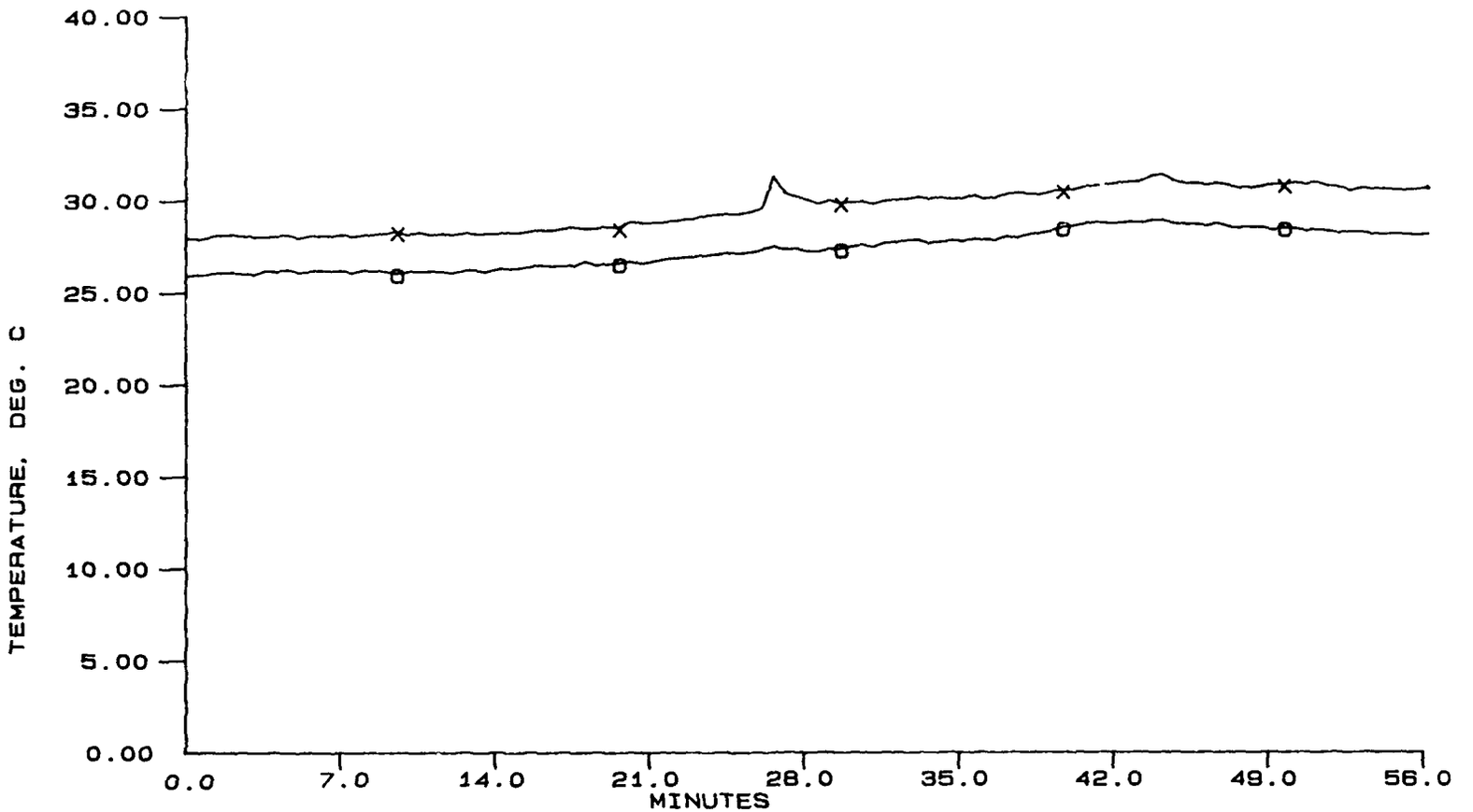


Fig. B-102 SMOKE CURTAIN TEST W-40 MAIN DECK CH 94 O, 98 X



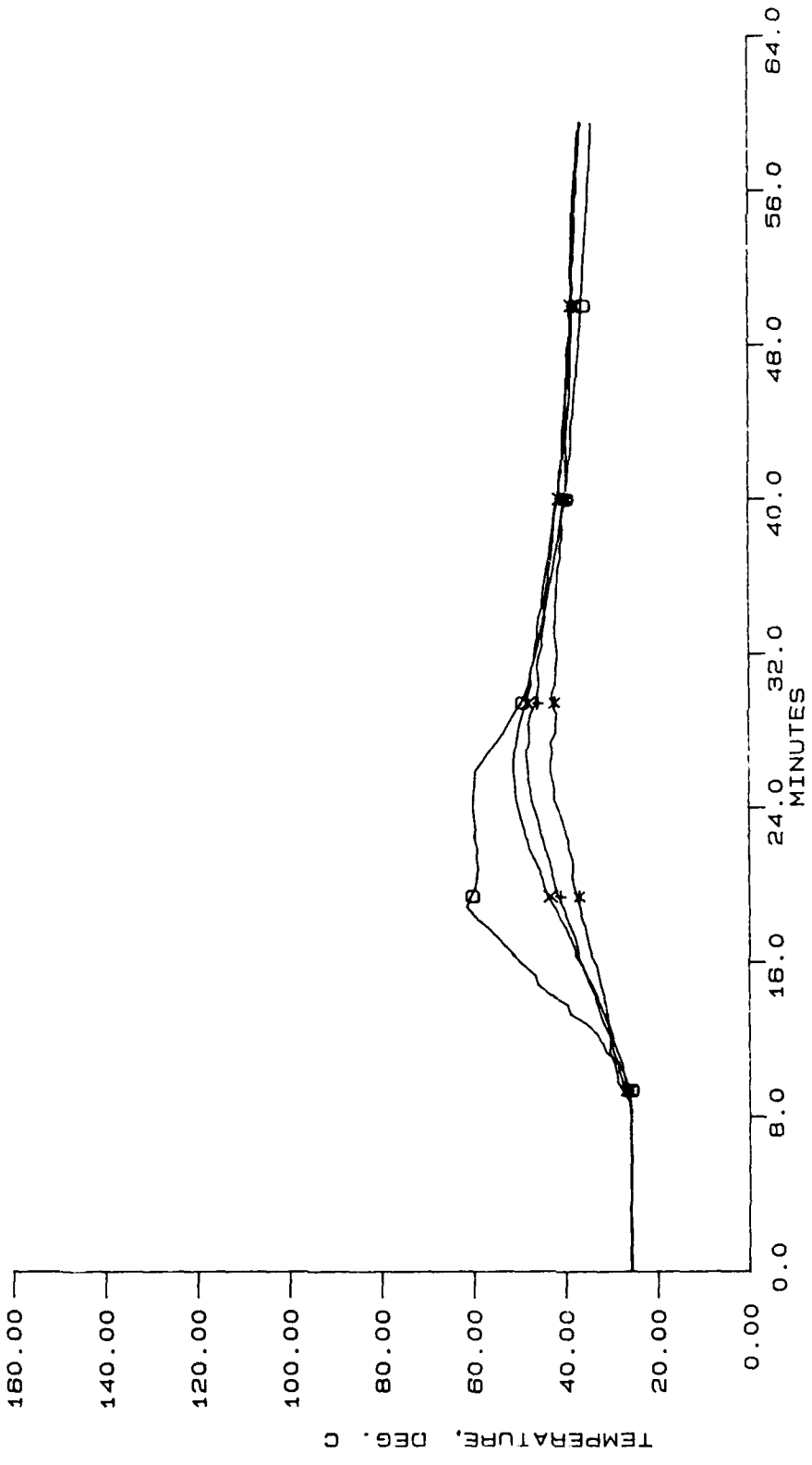


Fig. B-103 SMOKE CURTAIN TEST W-41 LEVEL 02 CH 116 ○, 117 X, 118 +, 119 ✳
TEMPERATURE, DEG. C
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0
8.0
16.0
24.0
32.0
40.0
48.0
56.0
64.0
MINUTES

Fig. B-104 SMOKE CURTAIN TEST W-41 LEVEL 02 CH 56 ○, 57 X, 58 +, 59 ✳

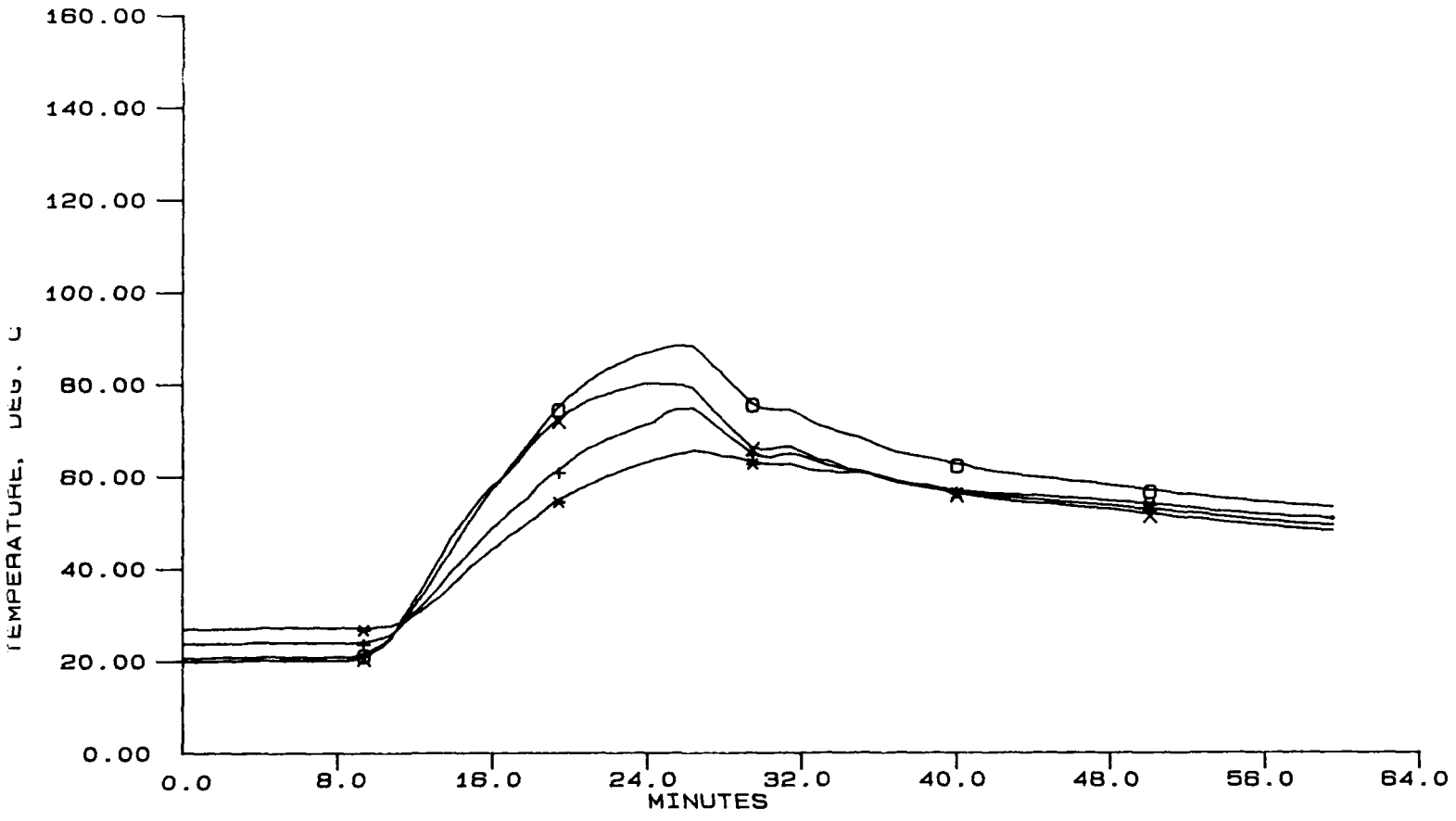


Fig. B-105 SMOKE CURTAIN TEST W-41 LEVEL 02 CH 52 ○, 53 ×, 54 +, 55 ✳

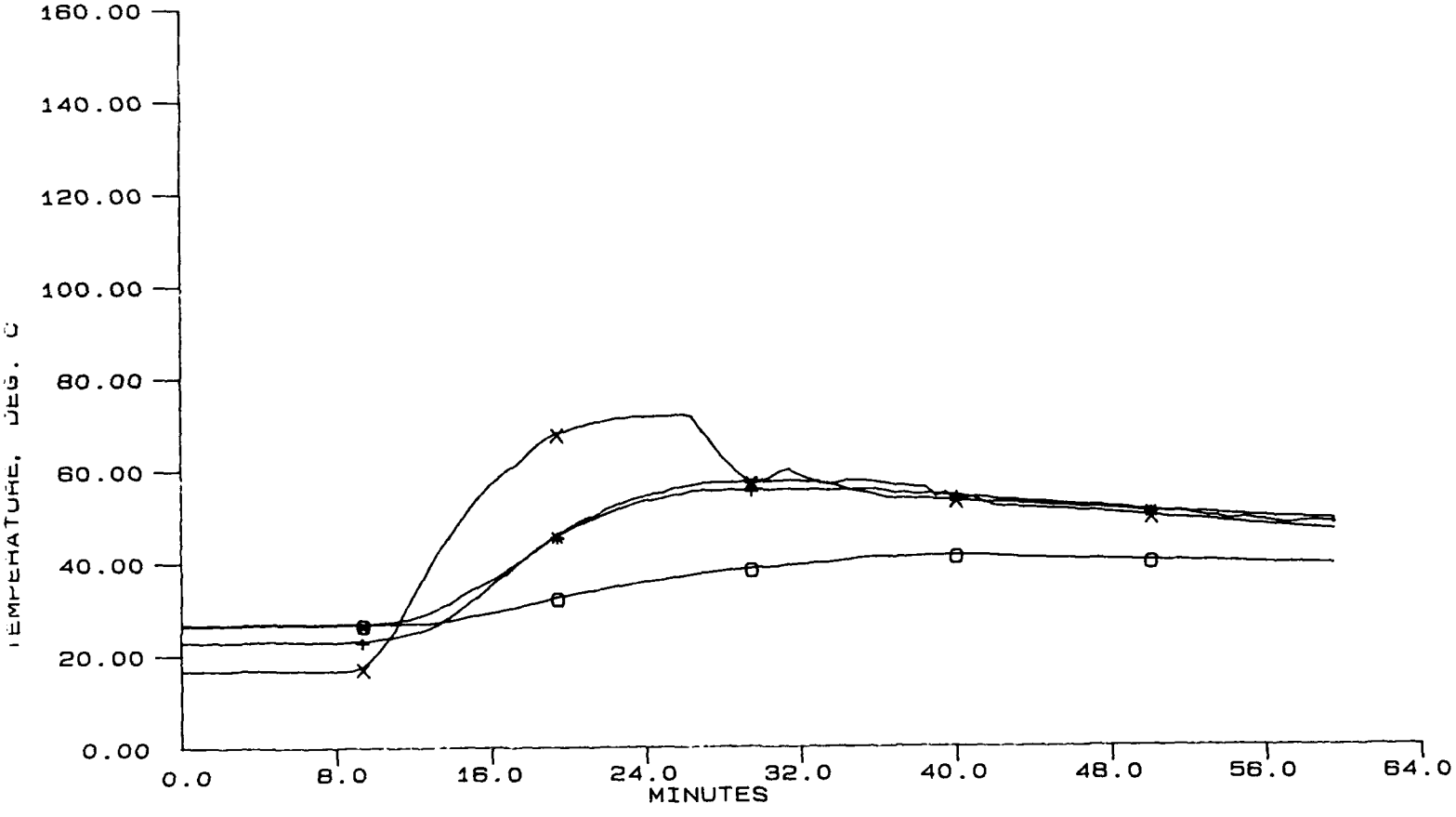


Fig. B-106 SMOKE CURTAIN TEST W-41 LEVEL 02 CH 48 ○, 49 X, 50 +, 51 ✳

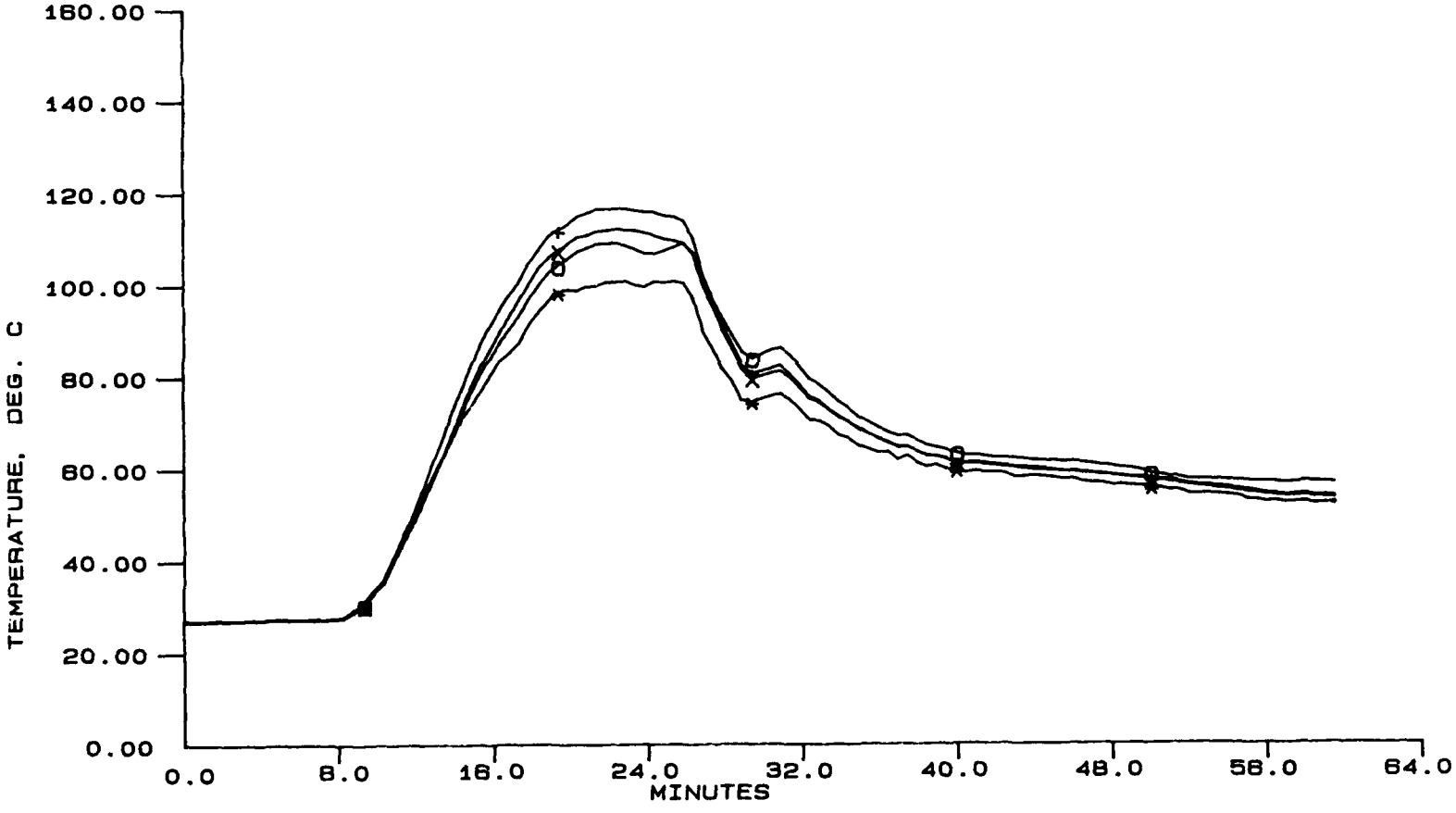


Fig. B-107 SMOKE CURTAIN TEST W-41 LEVEL 02 CH 44 ○, 45 ×, 46 +, 47 ✳

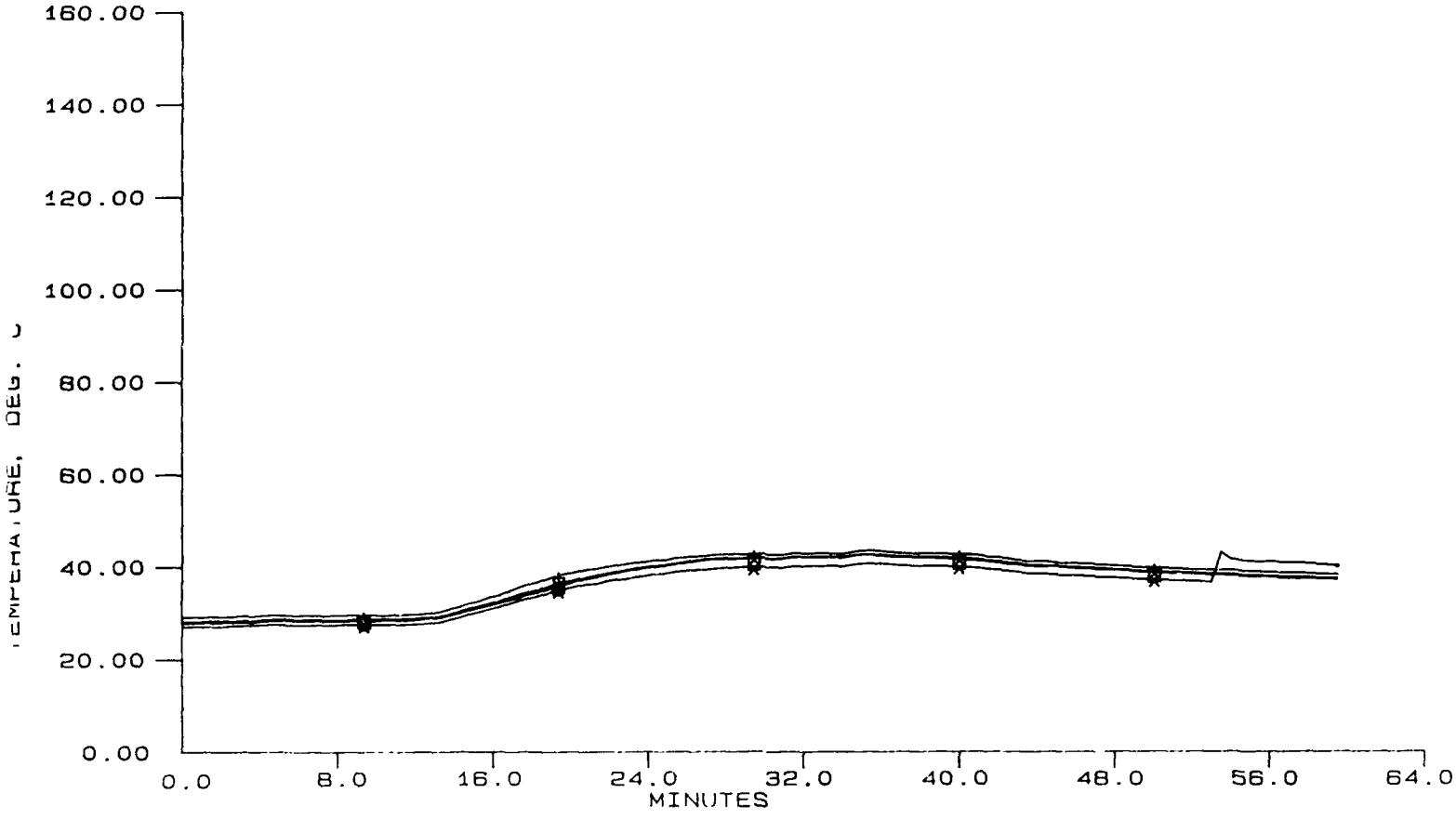
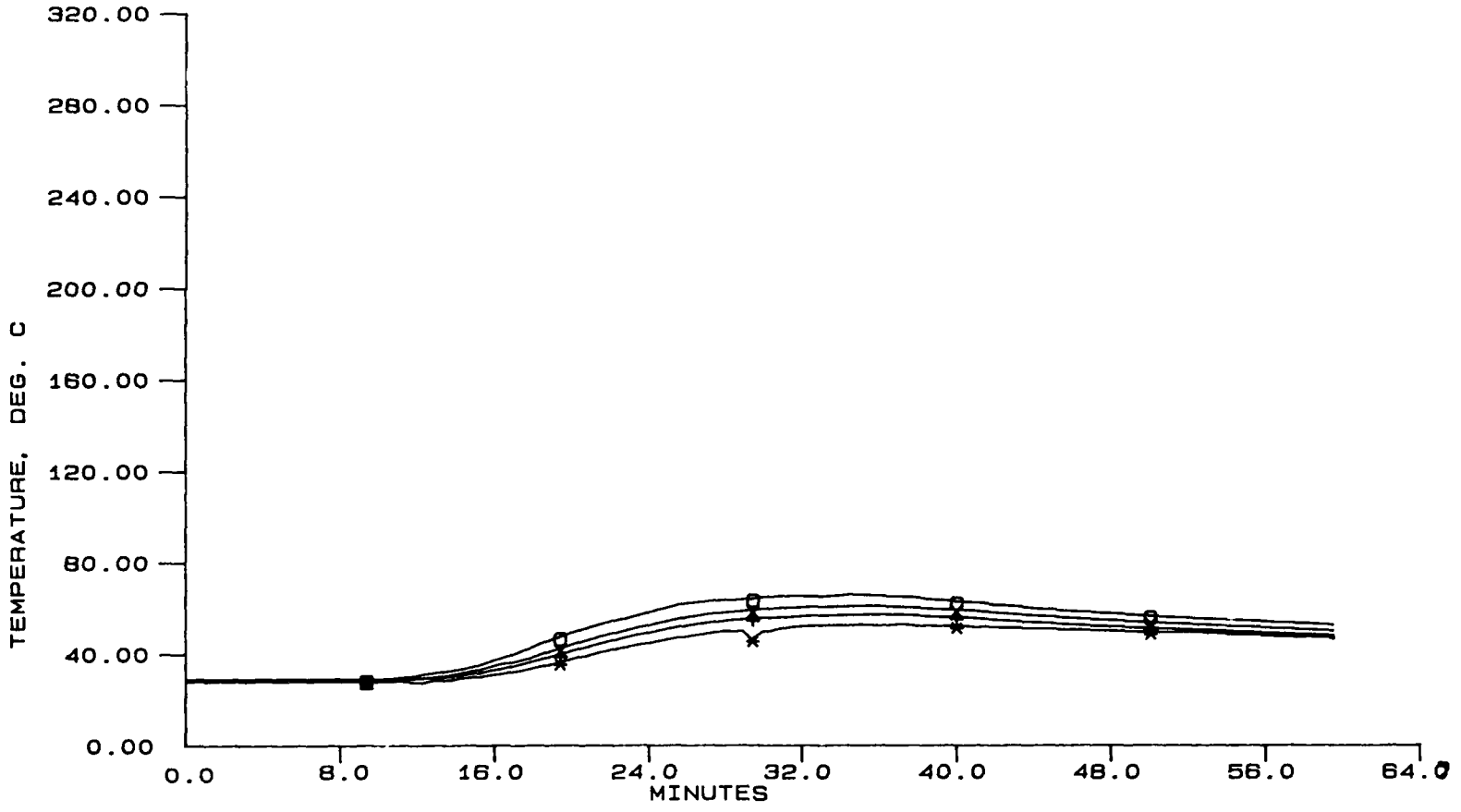


Fig. B-108 SMOKE CURTAIN TEST W-41 LEVEL 01 CH 72 ○, 73 X, 74 +, 75 ✳



151

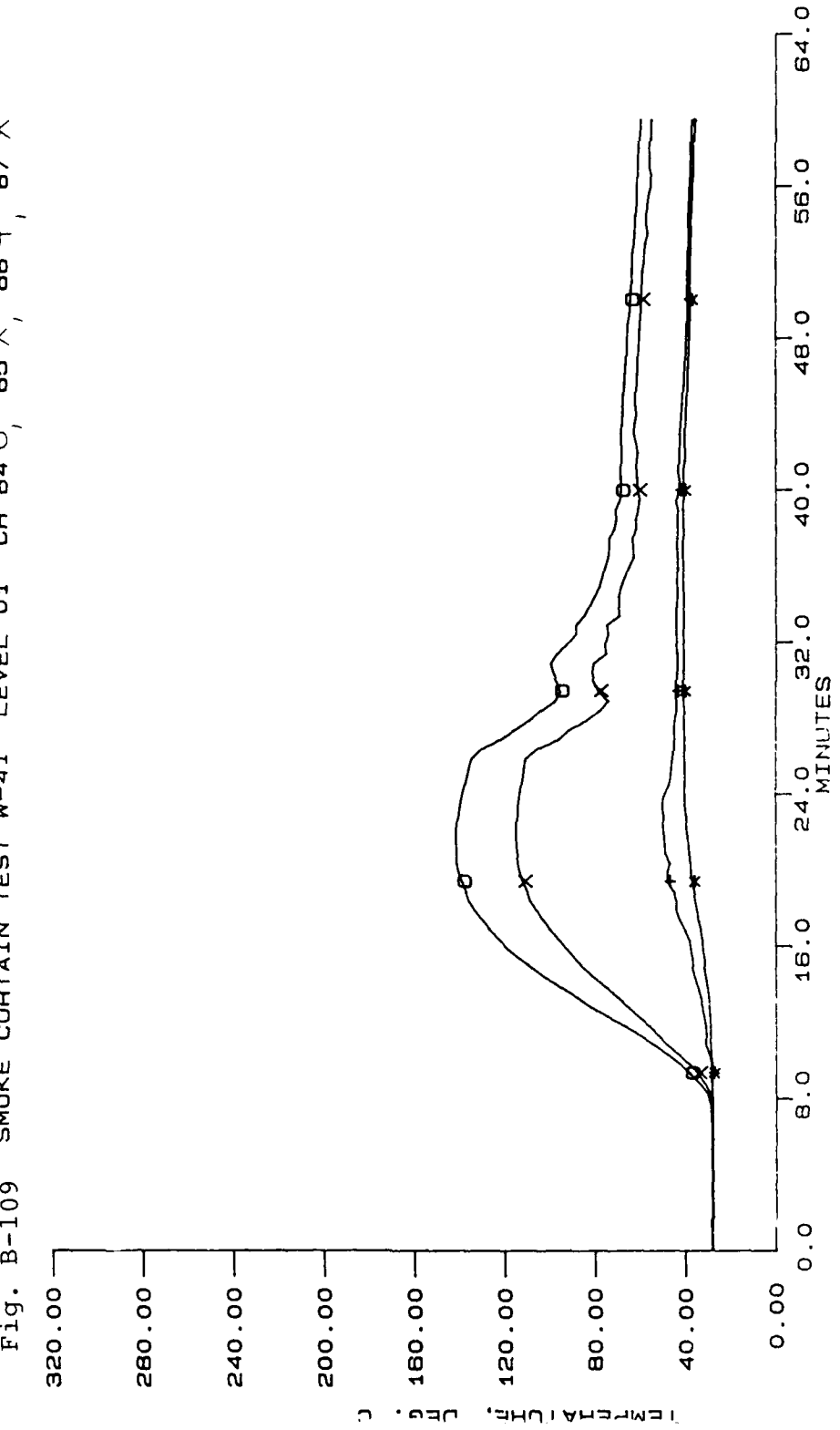


Fig. B-109 SMOKE CURTAIN TEST W-41 LEVEL 01 CH 64 O, 65 X, 66 +, 67 *
320.00
280.00
240.00
200.00
160.00
120.00
80.00
40.00
0.00
0.0
8.0
16.0
24.0
32.0
40.0
48.0
56.0
64.0
MINUTES

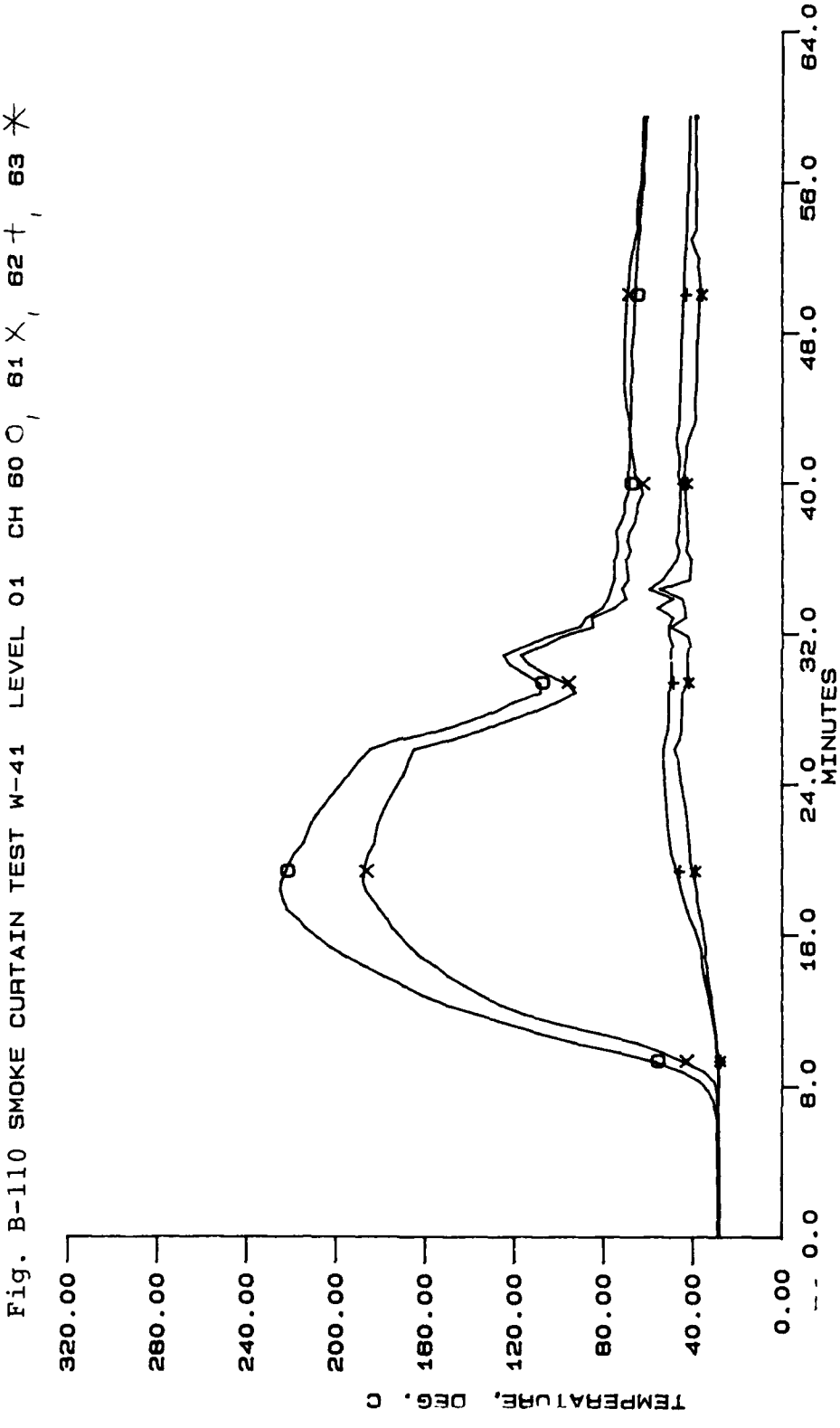


Fig. B-110 SMOKE CURTAIN TEST W-41 LEVEL 01 CH 60 O, 61 X, 62 +, 63 *
TEMPERATURE, DEG. C
320.00
280.00
240.00
200.00
160.00
120.00
80.00
40.00
0.00
0.0
8.0
16.0
24.0
32.0
40.0
48.0
56.0
64.0
MINUTES

Fig. B-111 SMOKE CURTAIN TEST W-41 LEVEL 01 CH 68 O, 69 X, 70 +, 71 ✳

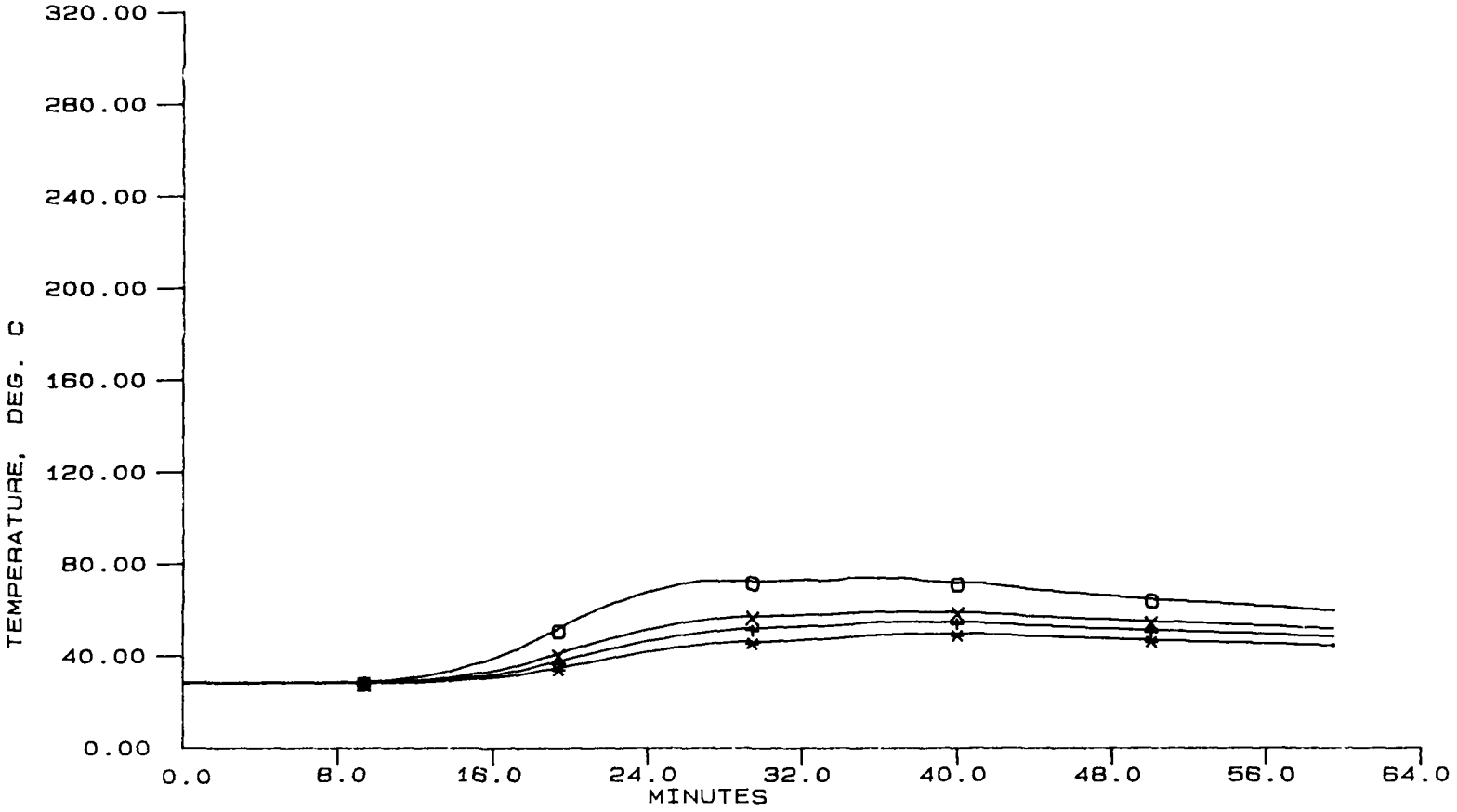


Fig. B-112 SMOKE CURTAIN TEST W-41 LEVEL 01 CH 112 ○, 113 X, 114 +, 115 ✳

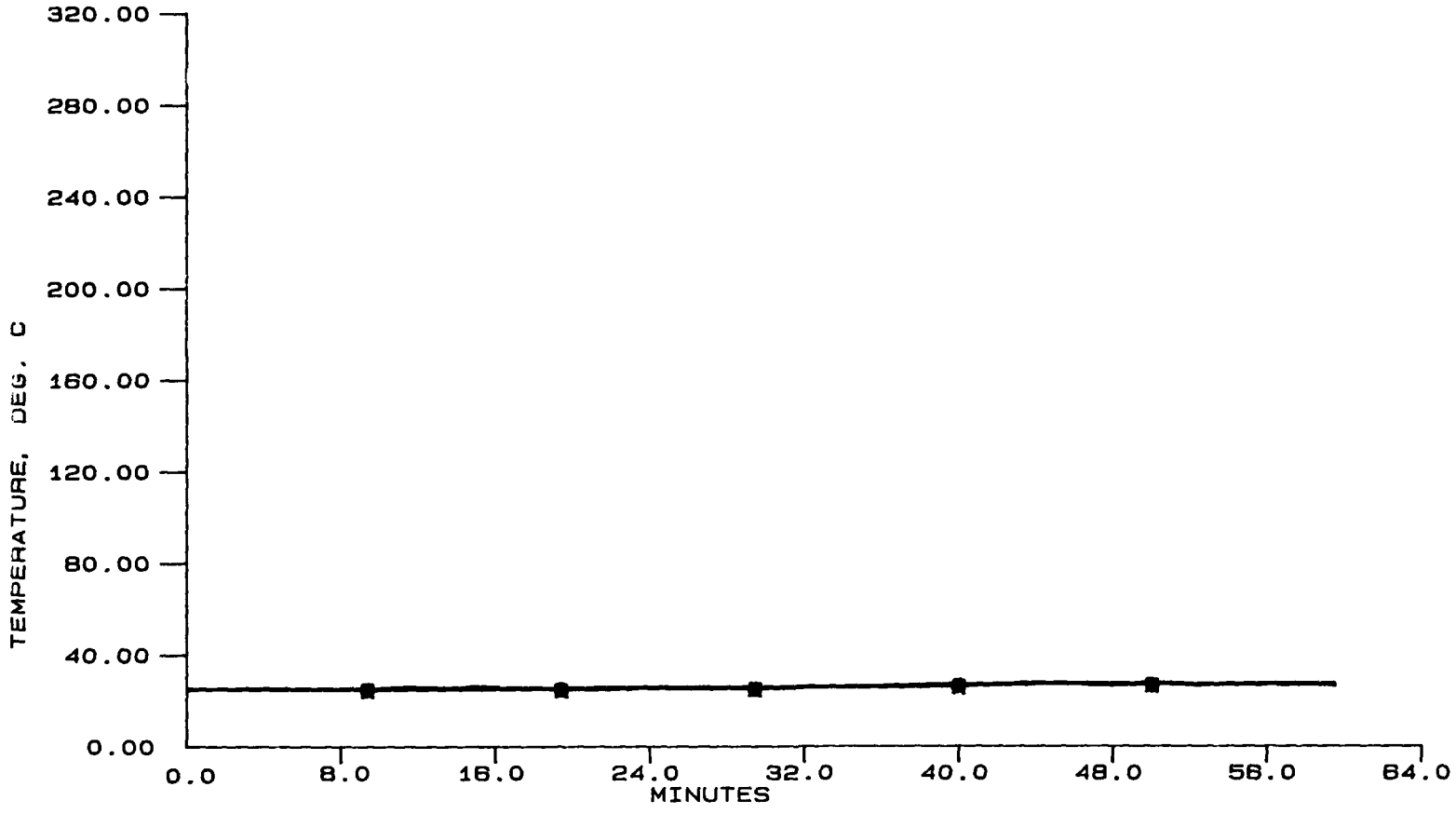


Fig. B-113 SMOKE CURTAIN TEST W-41 LEVEL 01 CH 76 ○, 77 X, 78 +, 79 ✳

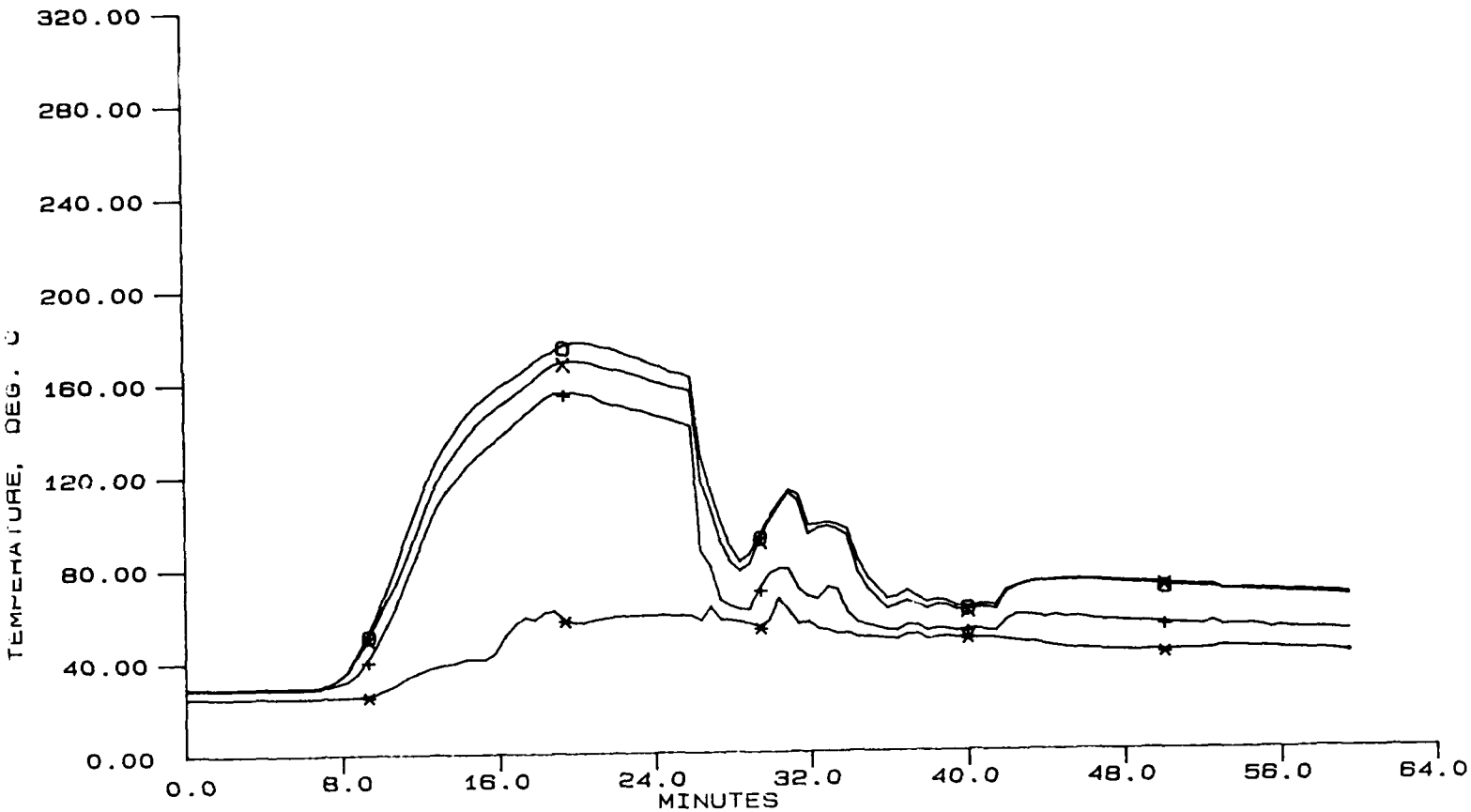


Fig. B-114 SMOKE CURTAIN TEST W-41 LEVEL 01 CH 80 ○, 81 X, 82 +, 83 ✳

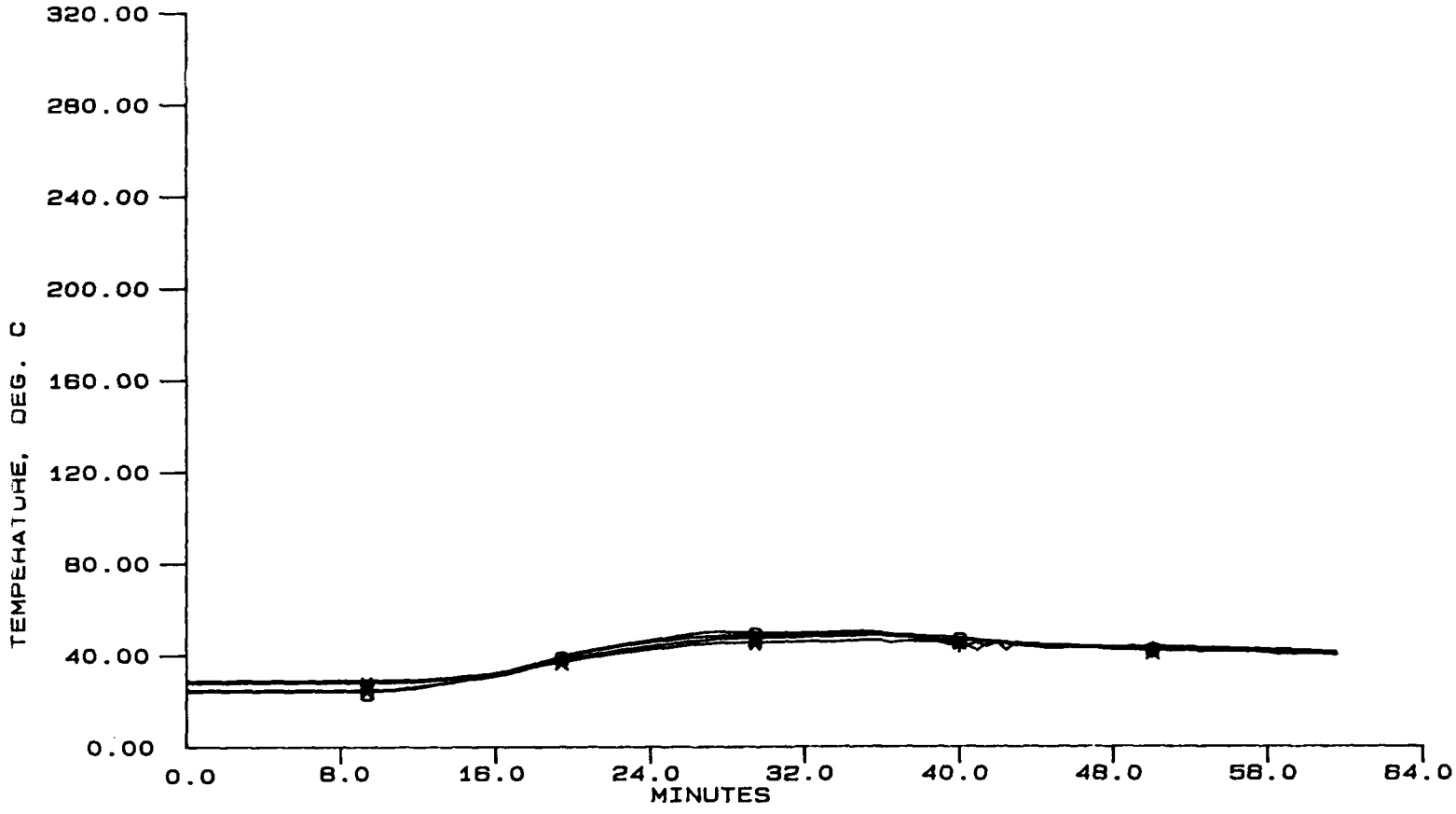


Fig. B-115 SMOKE CURTAIN TEST W-41 LEVEL 01 CH 84 O, 85 X, 86 +, 87 *

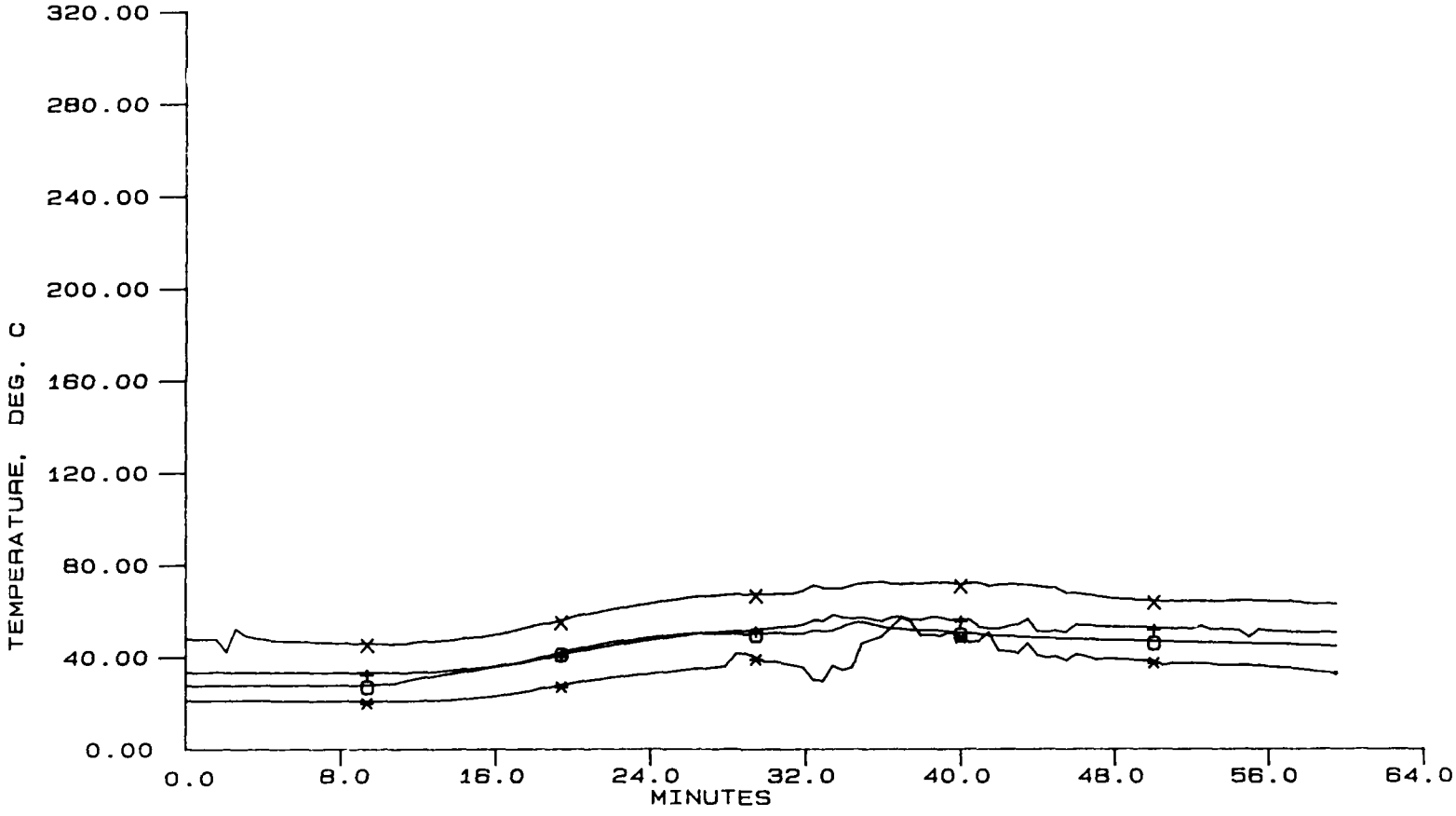


Fig. B-116 SMOKE CURTAIN TEST W-41 MAIN DECK CH 104 ○, 105 X, 106 +, 107 ✳

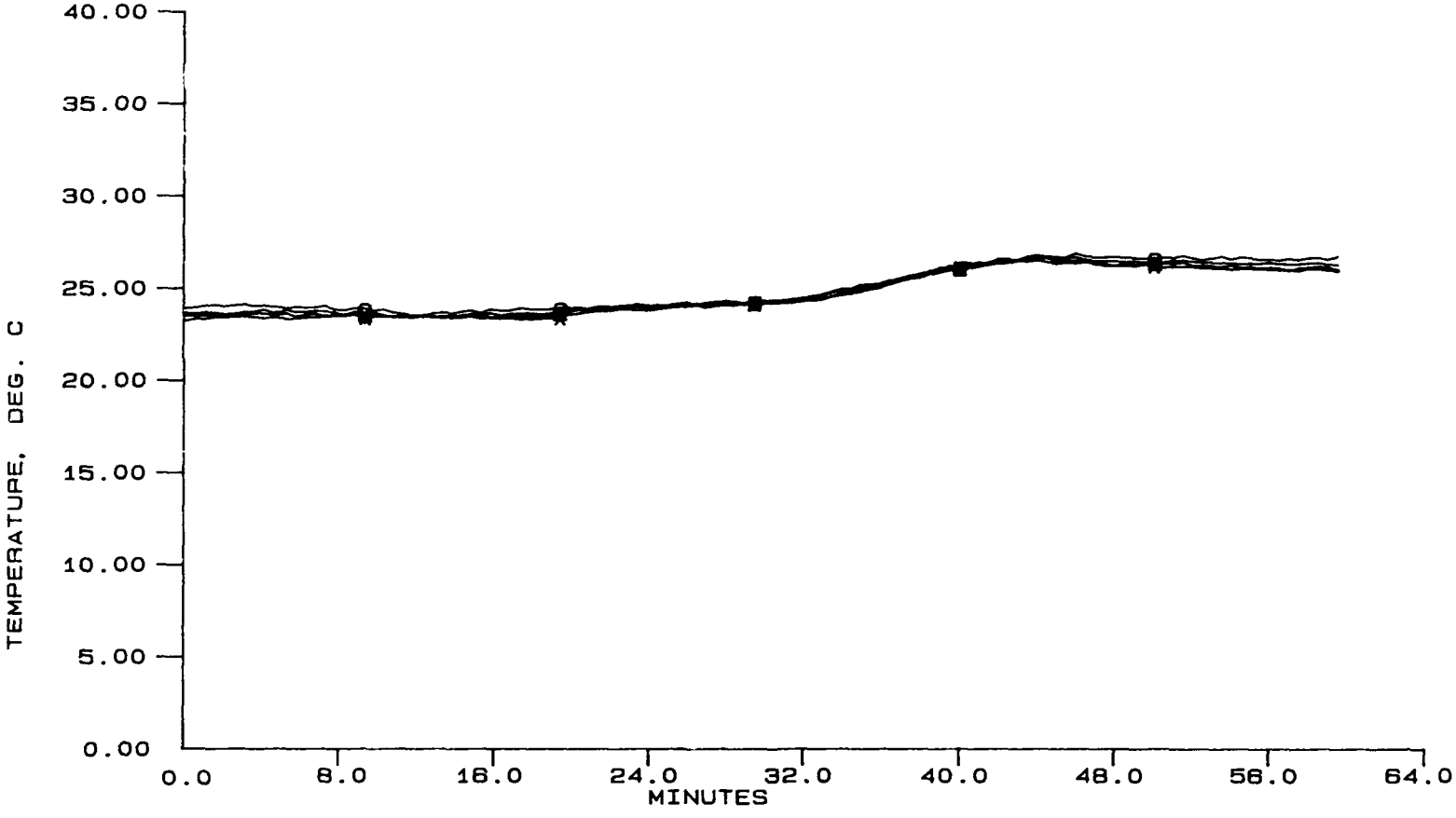


Fig. B-117 SMOKE CURTAIN TEST W-41 MAIN DECK CH 100 ○, 101 X, 102 +, 103 ✳

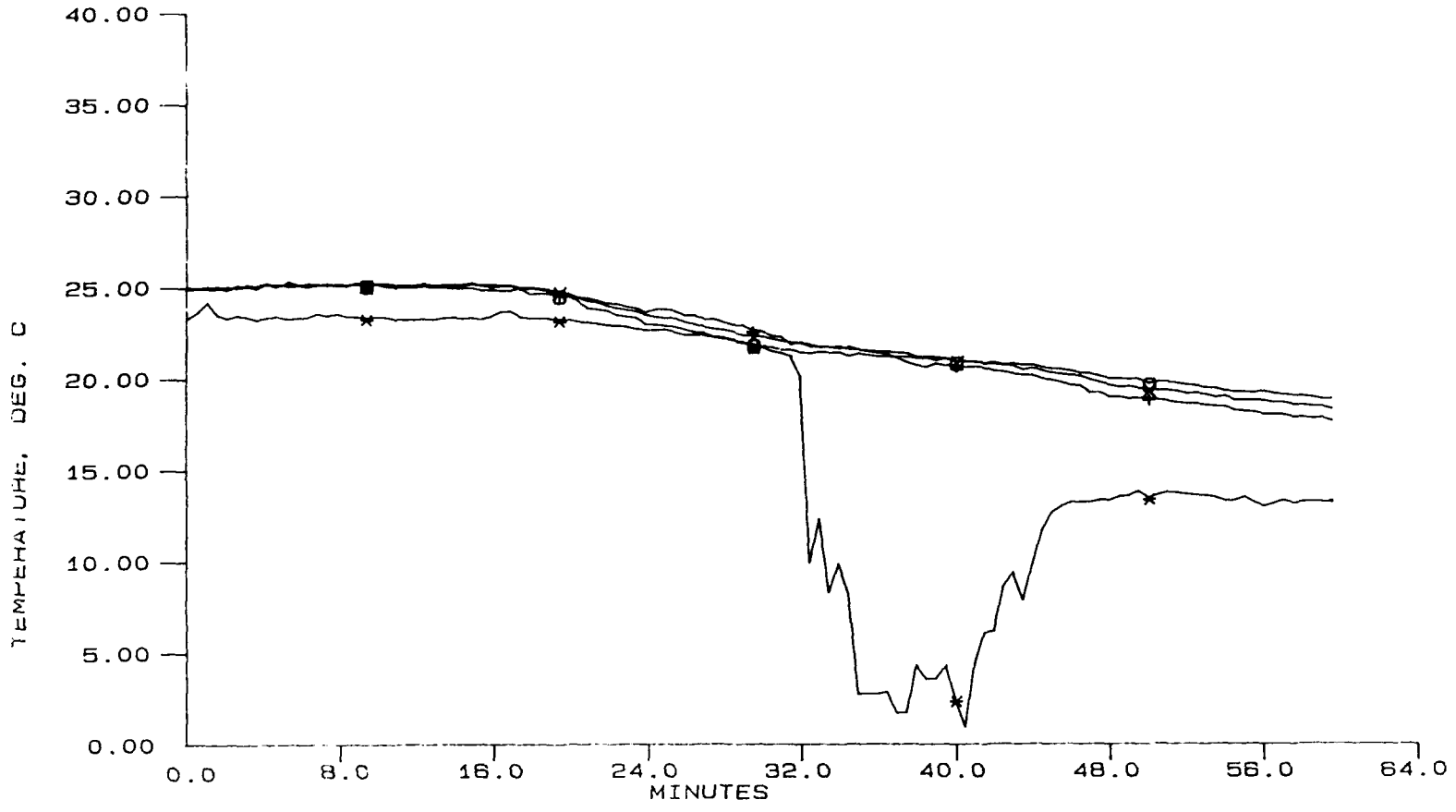


Fig. B-118 SMOKE CURTAIN TEST W-41 MAIN DECK CH 108 ○, 109 ×, 110 +, 111 ✳

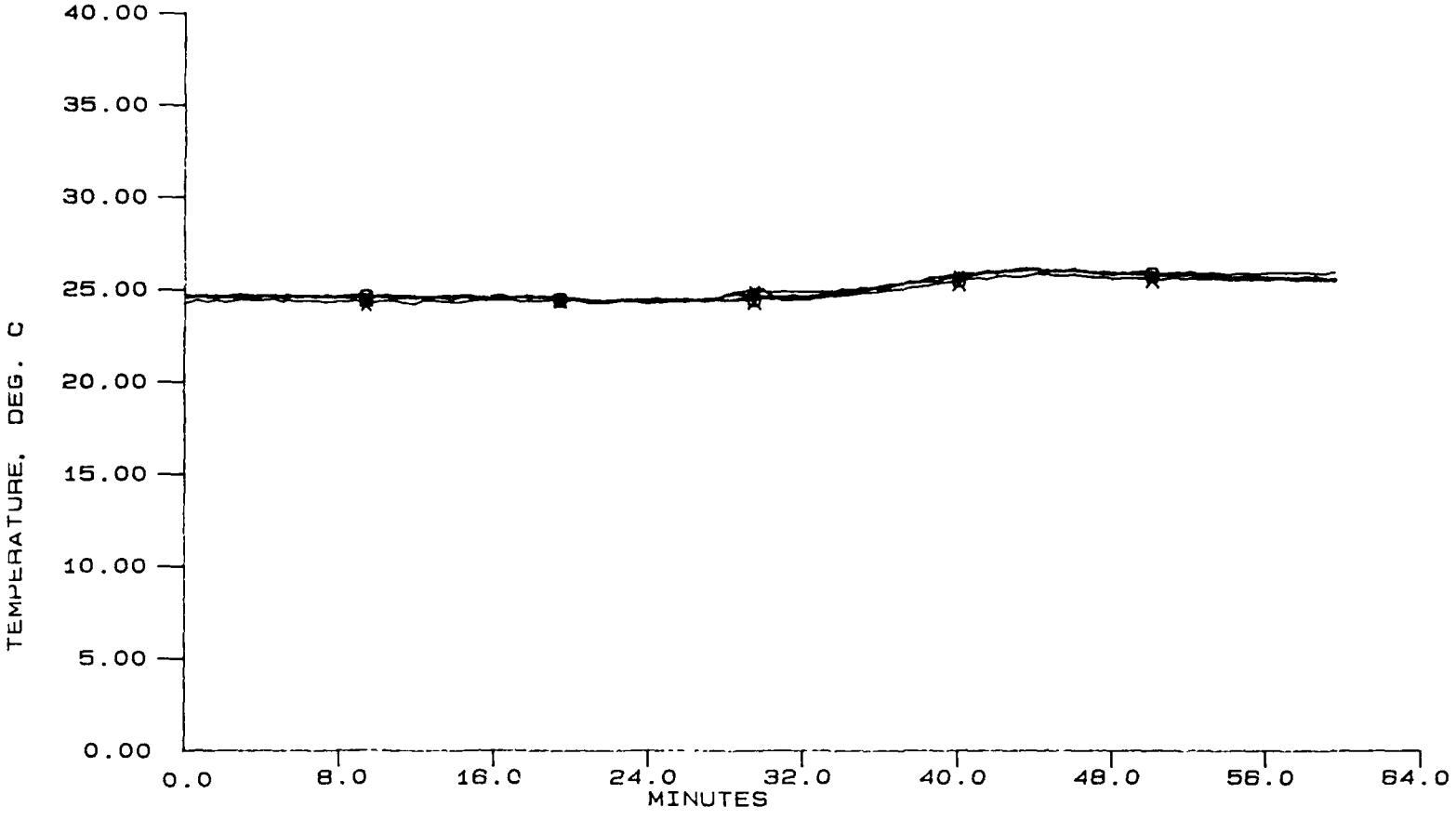


Fig. B-119 SMOKE CURTAIN TEST W-41 MAIN DECK CH 94 O, 98 X

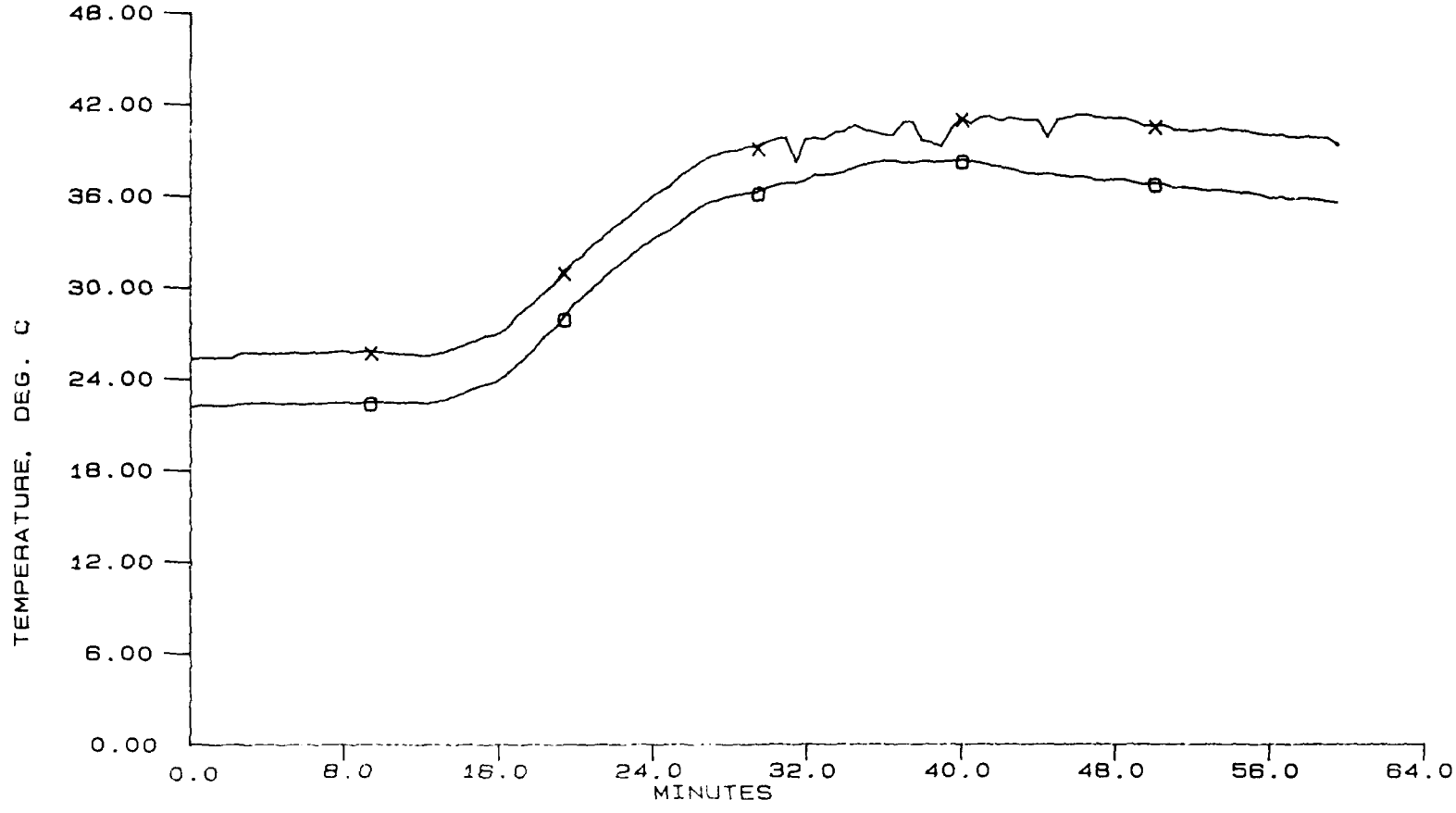


Fig. B-120 SMOKE CURTAIN TEST W-42 LEVEL 02 CH 116 O, 117 X, 118 +, 119 ✳

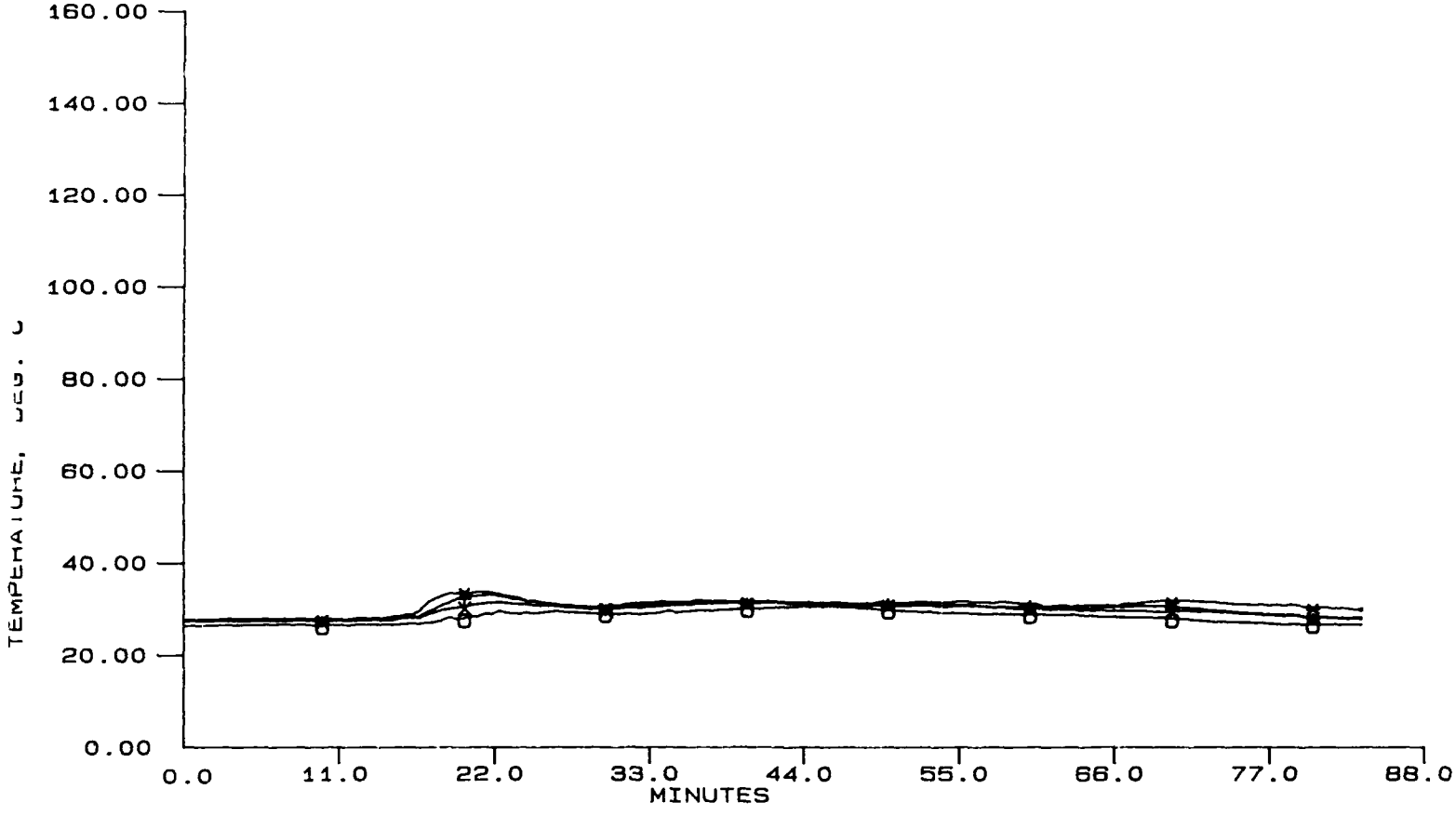


Fig. B-121 SMOKE CURTAIN TEST W-42 LEVE 02 CH 56 ○, 57 X, 58 +, 59 ✳

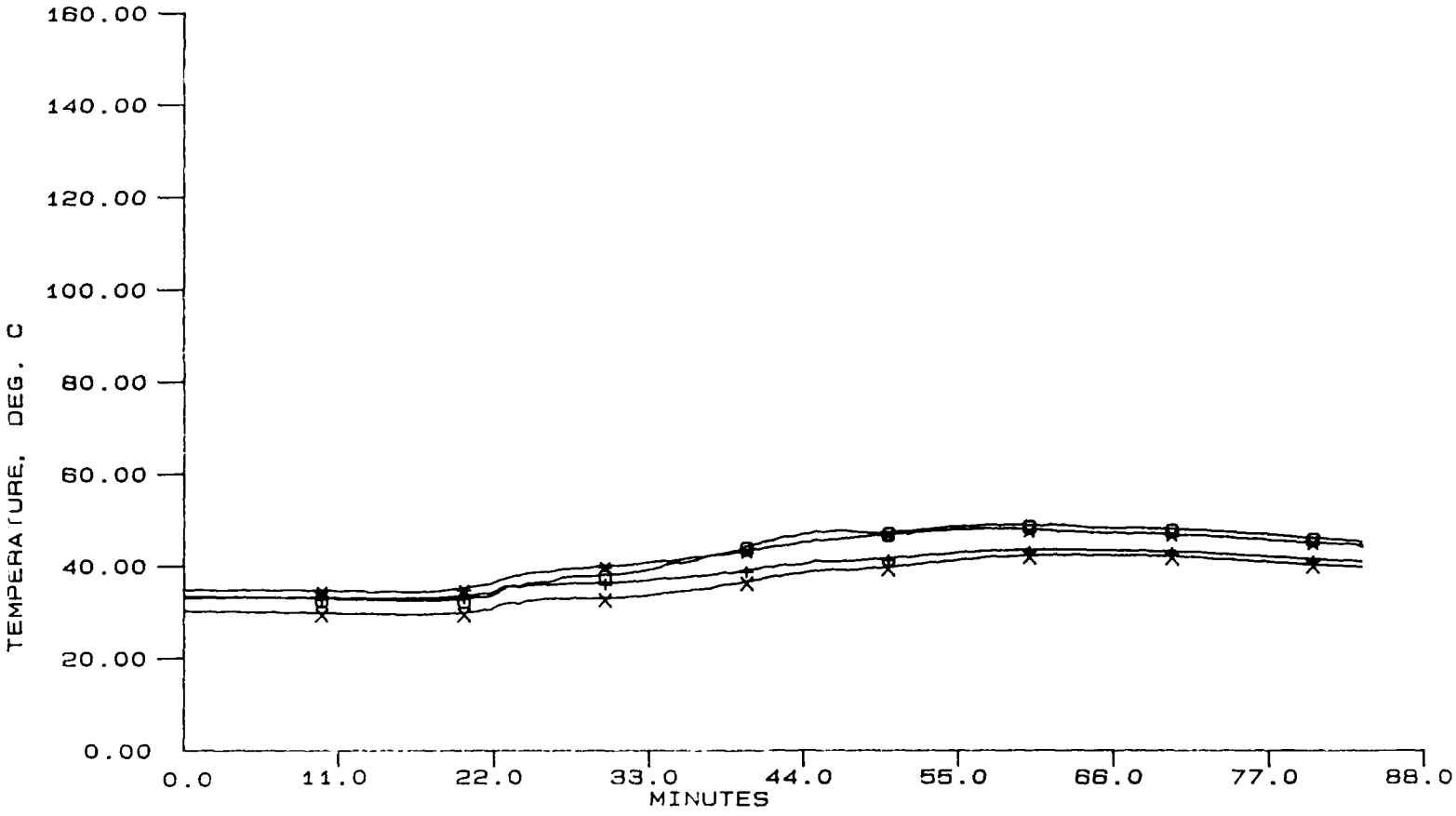
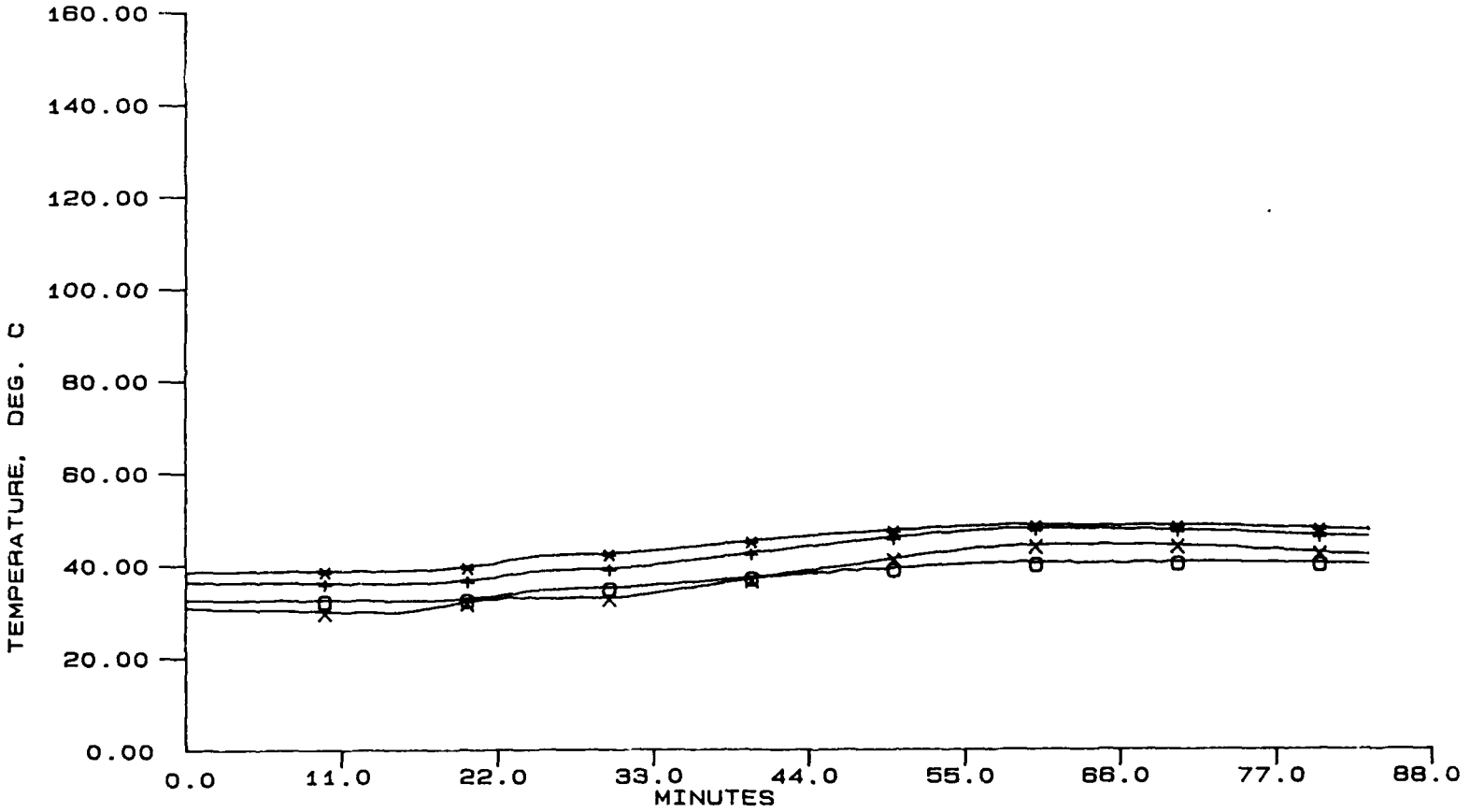


Fig. B-122 SMOKE CURTAIN TEST W-42 LEVEL 02 CH 52 ○, 53 X, 54 +, 55 ✳



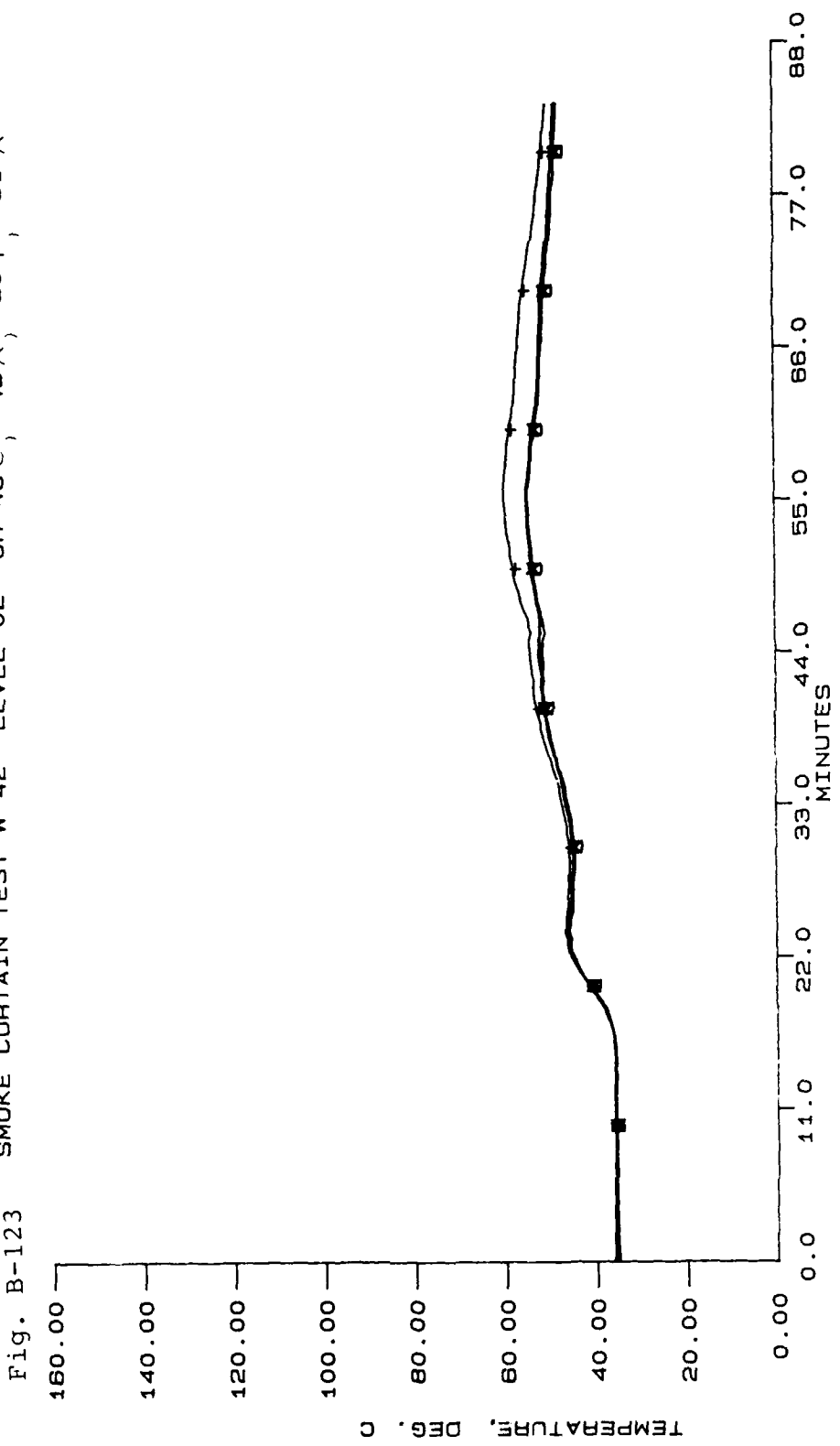

SMOKE CURTAIN TEST W-42 LEVEL 02 CH 48 ○, 49 X, 50 +, 51 ✳
TEMPERATURE, DEG. C
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.0
11.0
22.0
33.0
44.0
55.0
66.0
77.0
88.0
MINUTES

Fig. B-123

Fig. B-124 SMOKE CURTAIN TEST W-42 LEVEL 02 CH 44 ○, 45 X, 46 +, 47 ✳

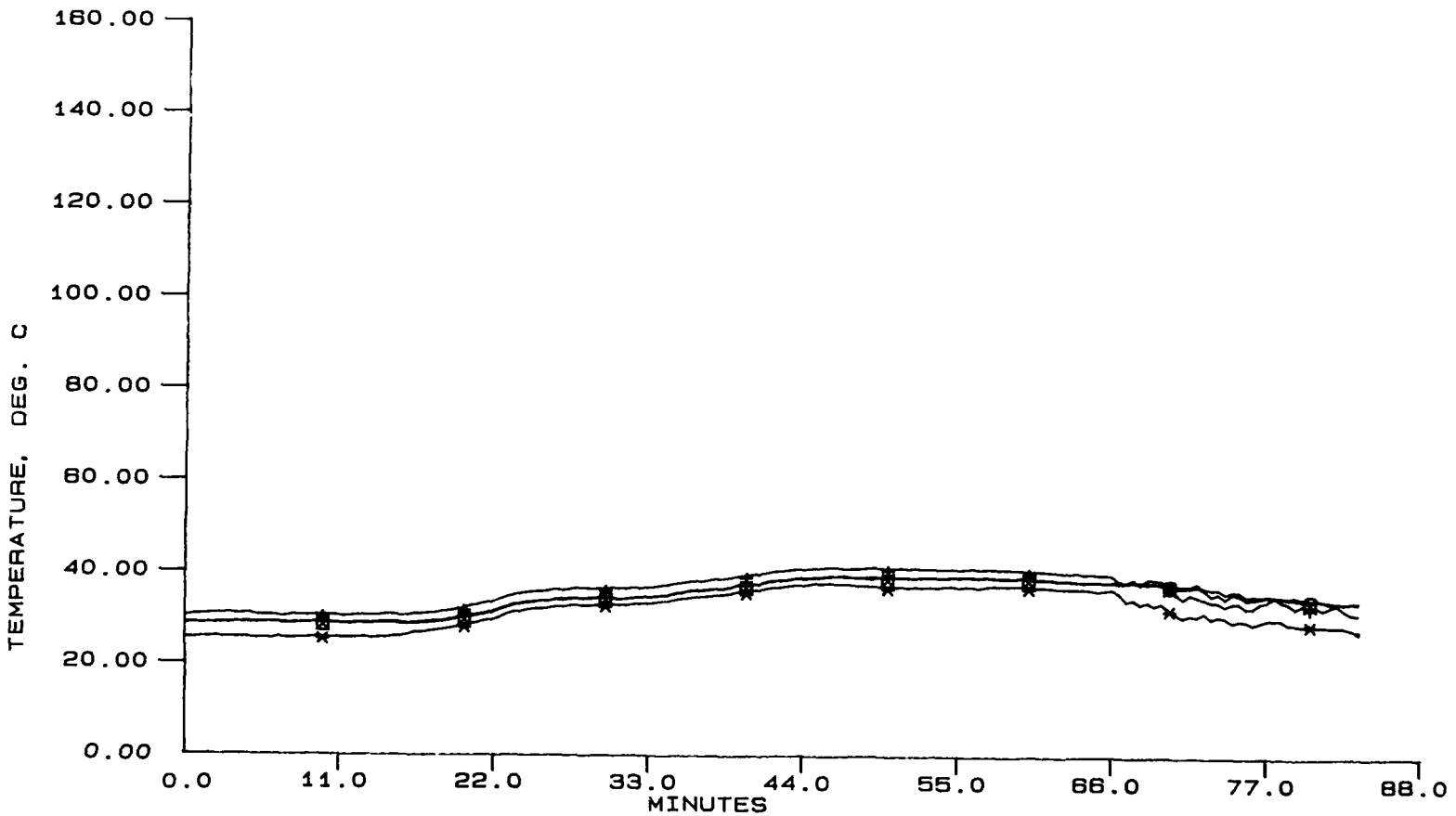


Fig. B-125 SMOKE CURTAIN TST W-42 LEVEL 01 CH 72 ○, 73 X, 74 +, 75 ✳

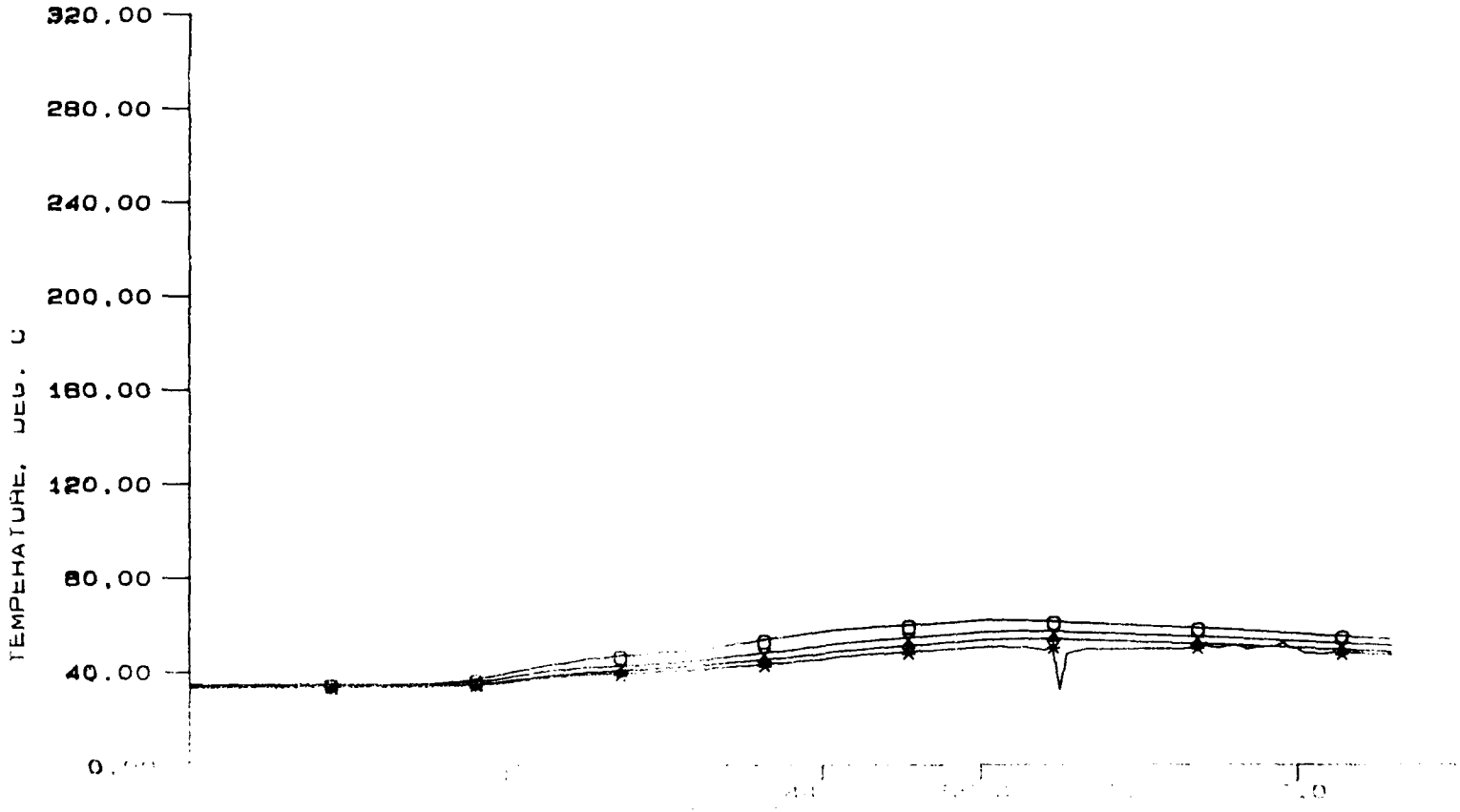


Fig. B-126 SMOKE CURTAIN TEST W-42 LEVEL 01 CH 64 O, 65 X, 66 +, 67 *

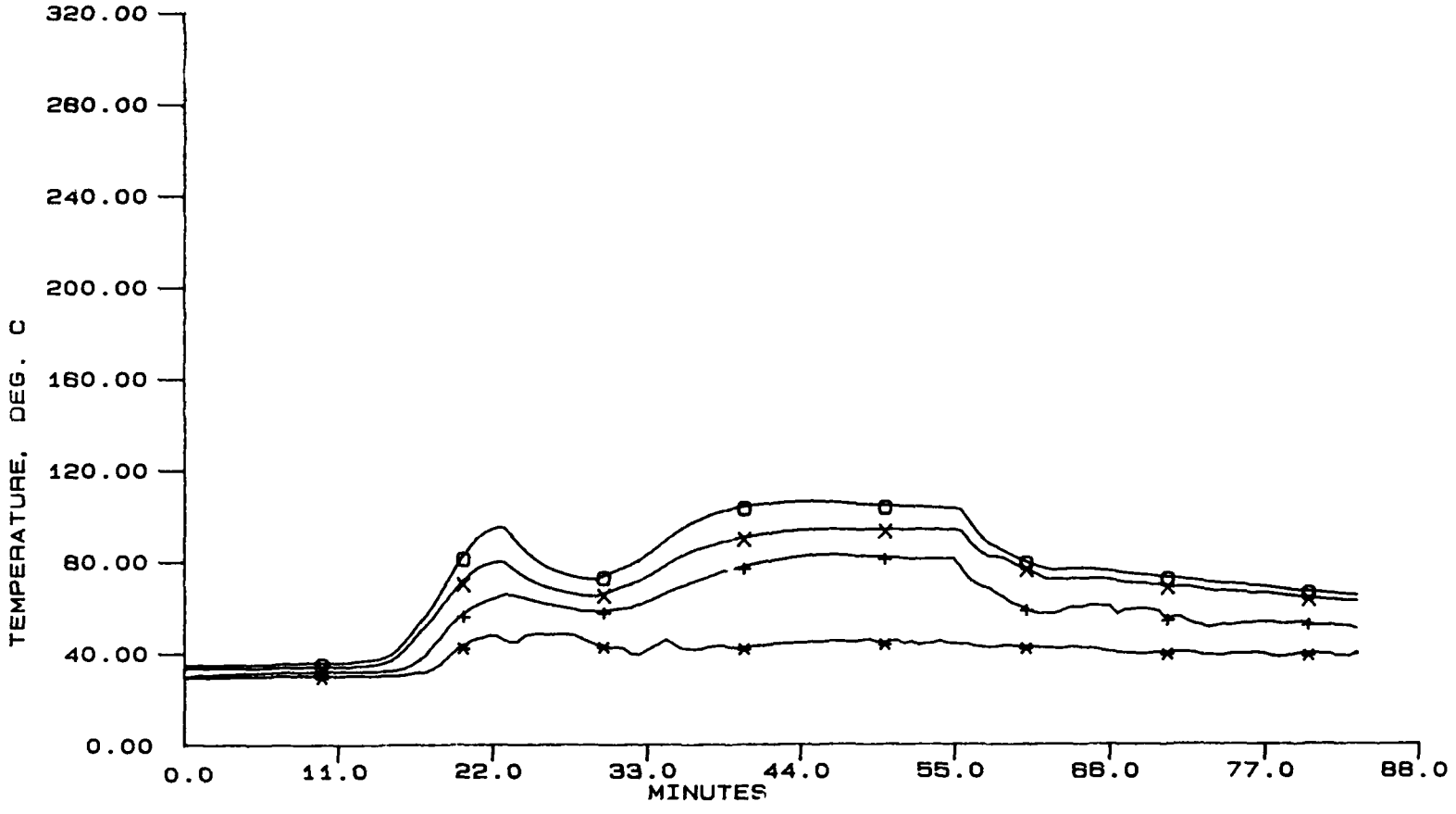


Fig. B-127 SMOKE CURTAIN TEST W-42 LEVEL 01 CH 60 ○, 61 ×, 62 +, 63 ✳

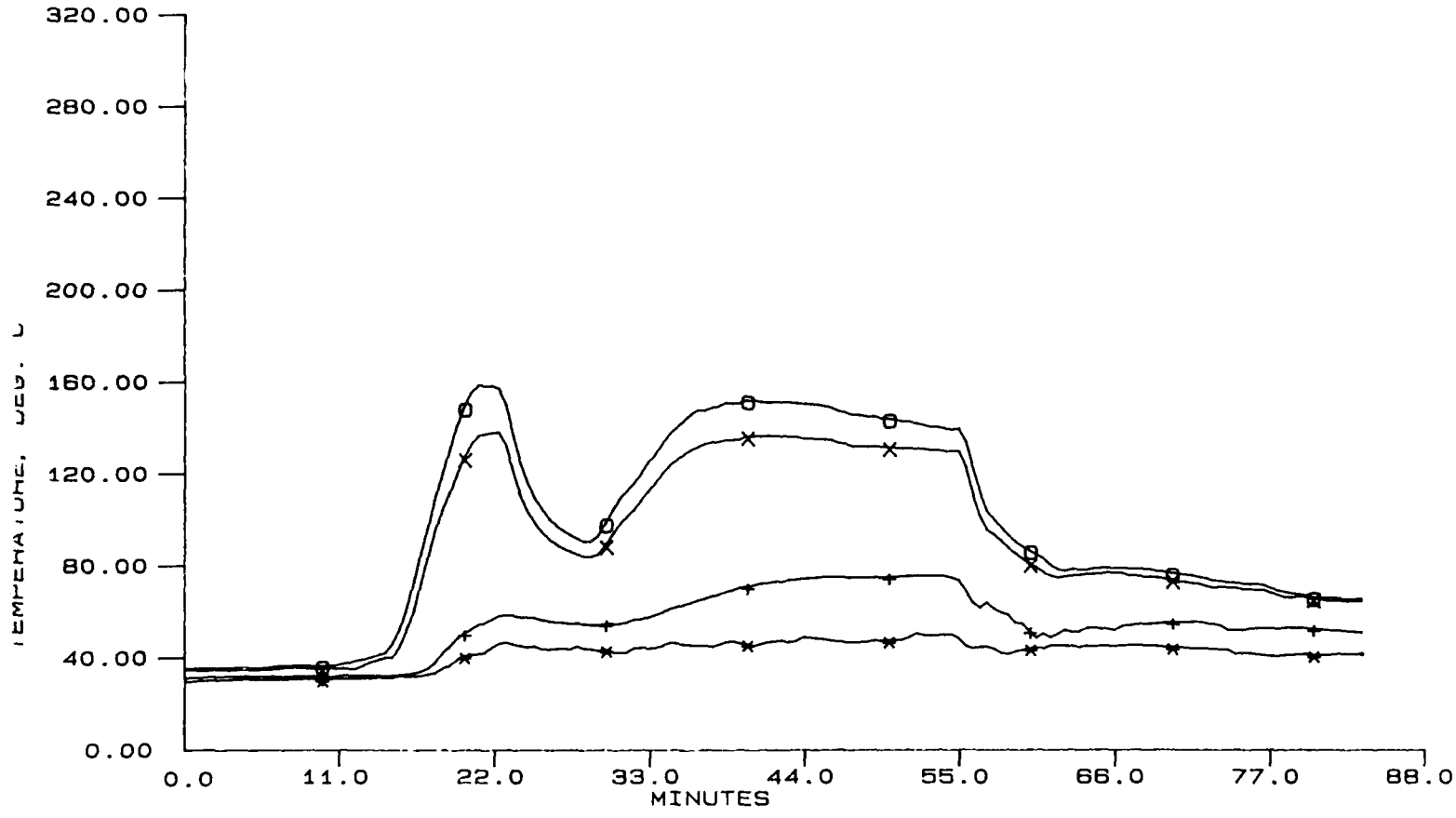


Fig. B-128 SMOKE CURTAIN TEST W-42 LEVEL 01 H 68 ○, 69 X, 70 +, 71 ✳

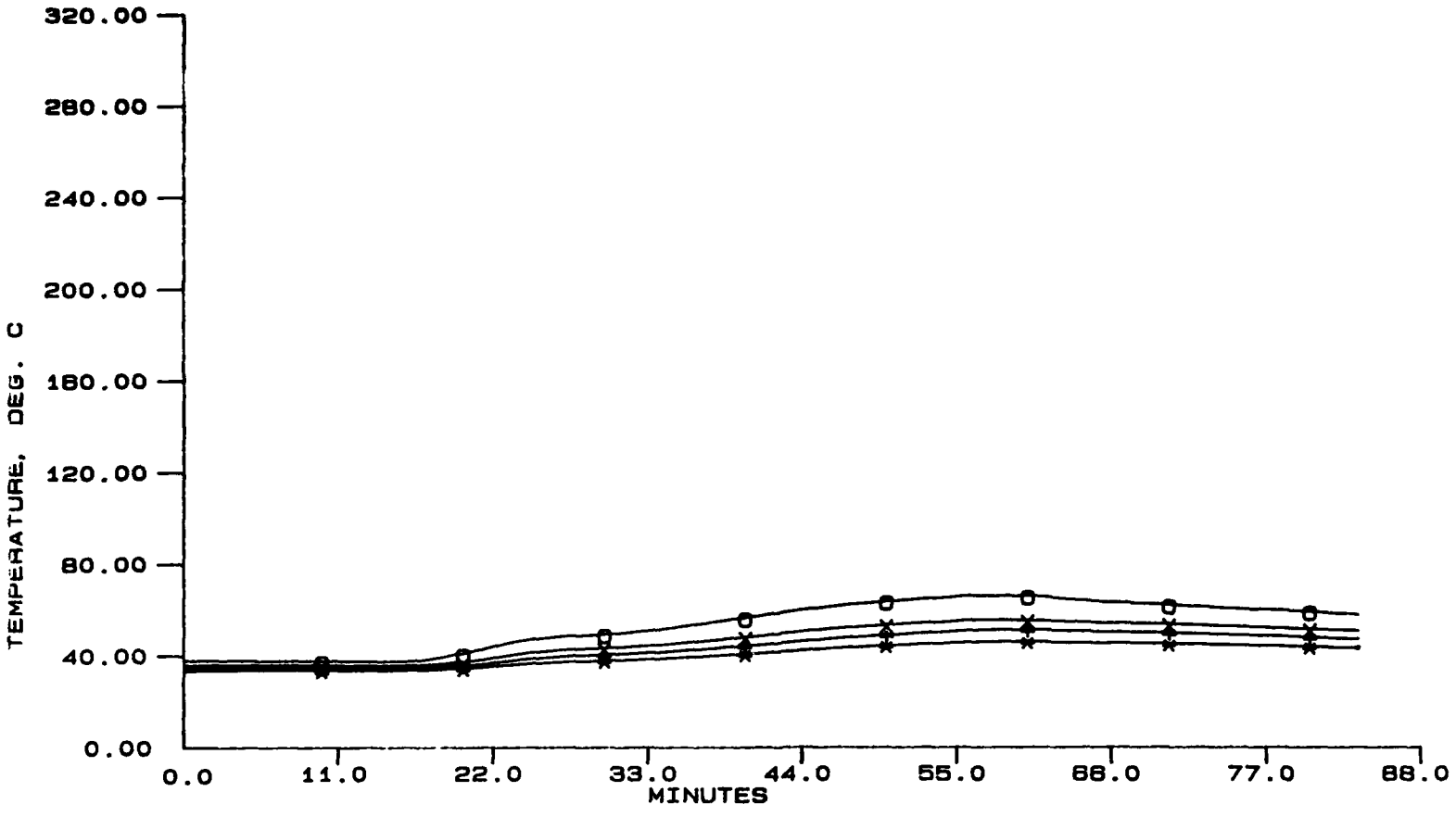


Fig. B-129 SMOKE CURTAIN TEST W-42 LEVEL 01 CH 112 O, 113 X, 114 +, 115 ✳

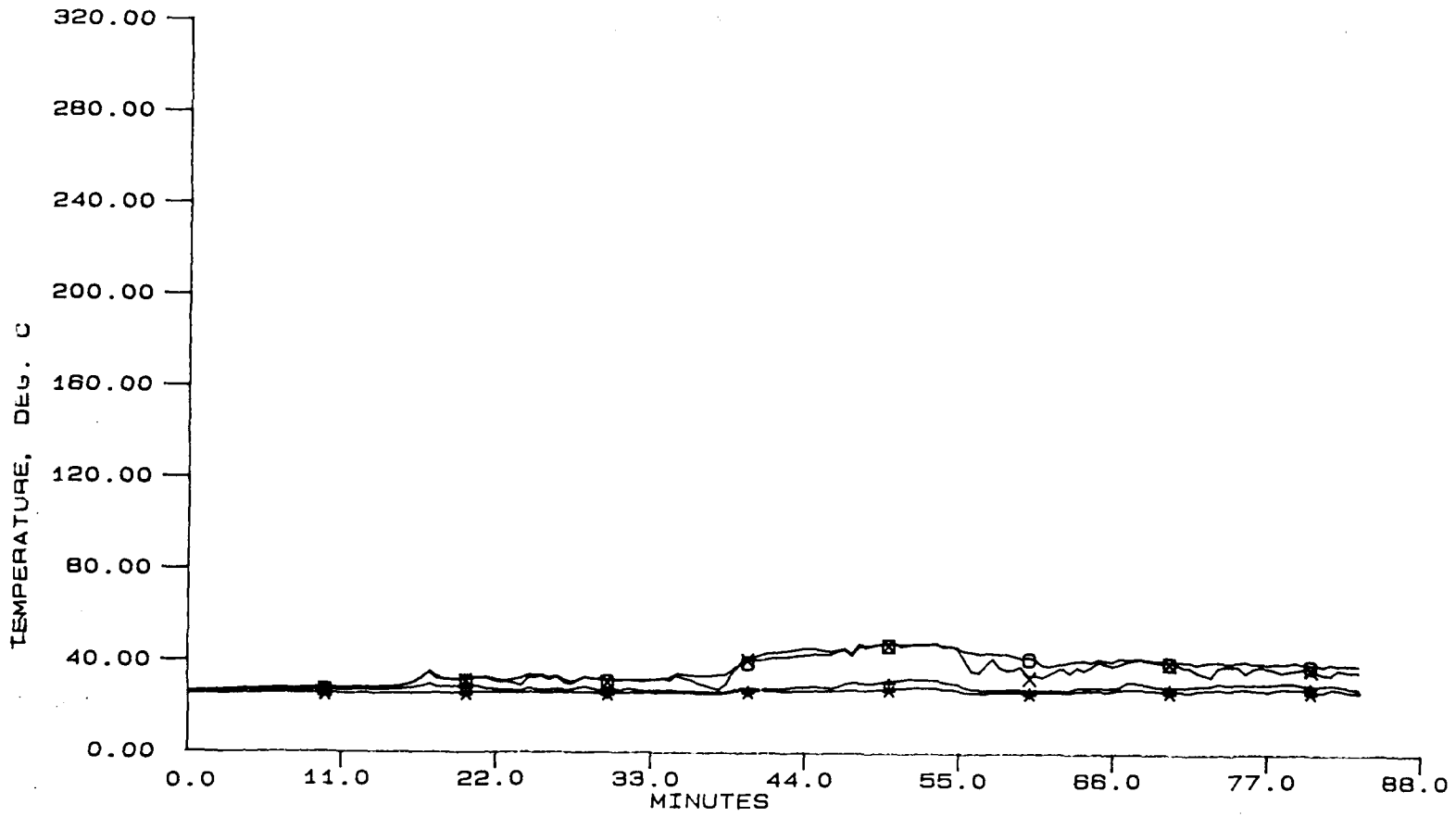


Fig. B-130 SMOKE CURTAIN TEST W-42 LEVEL 01 CH 76 ○, 77 X, 78 +, 79 ✳

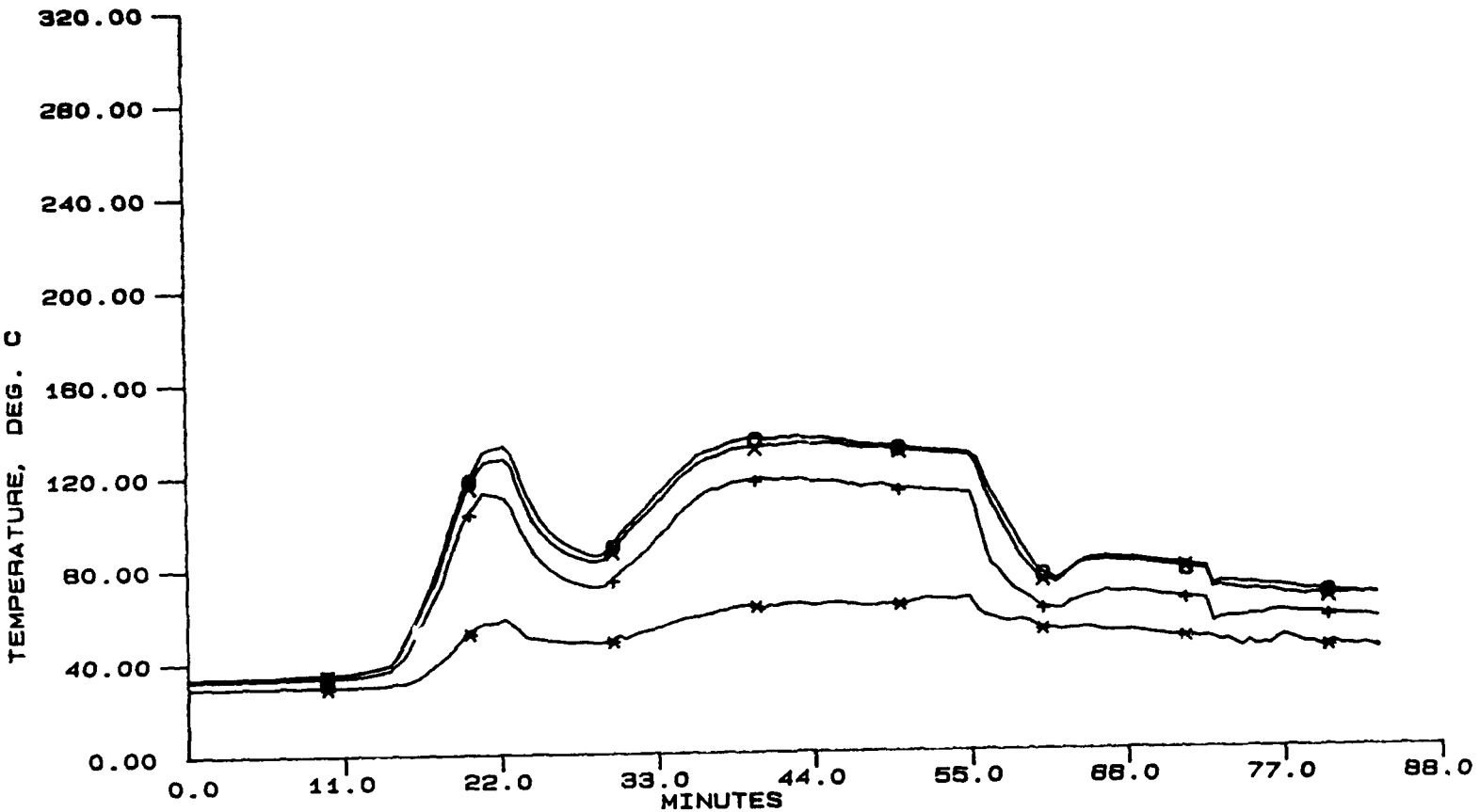


Fig. B-131 SMOKE CURTAIN TEST W-42 LEVEL 01 CH 80 ○, 81 X, 82 +, 83 ✳

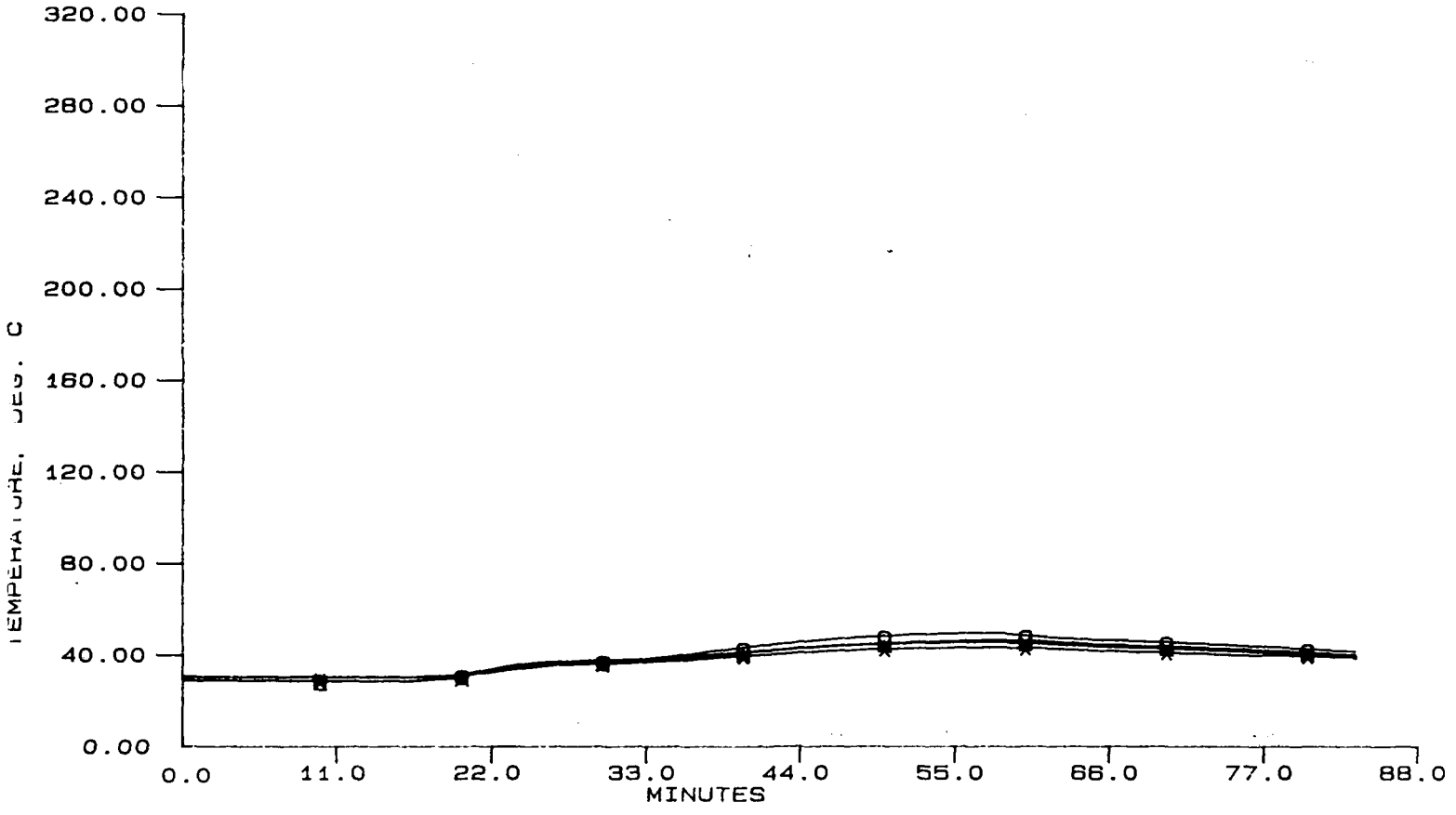


Fig. B-132 SMOKE CURTAIN TEST W-42 LEVEL 01 CH 84 ○, 85 X, 86 +, 87 ✳

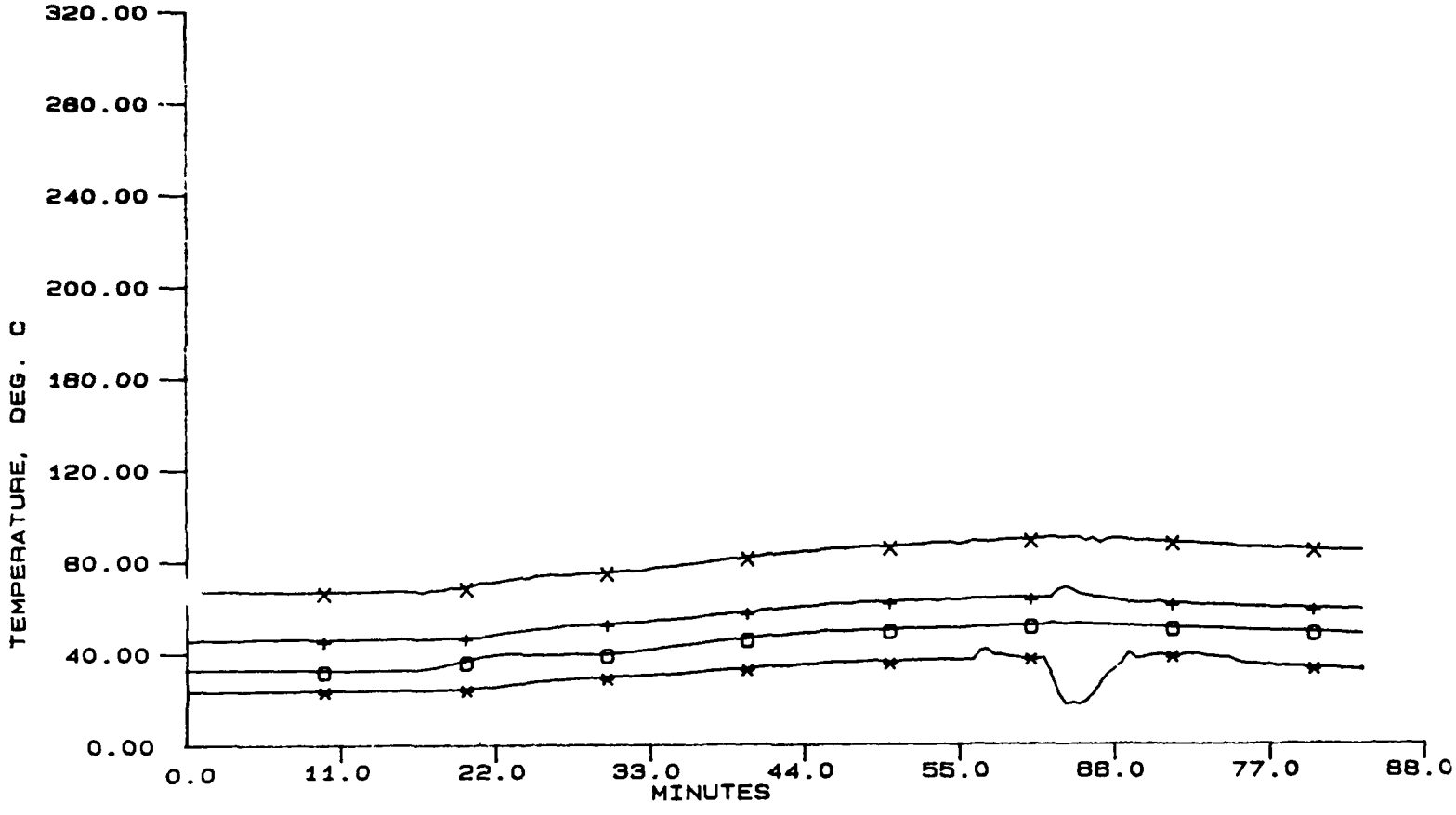


Fig. B-133 SMOKE CURTAIN TEST W-42 MAIN DECK CH 104 ○, 105 X, 106 +, 107 ✳

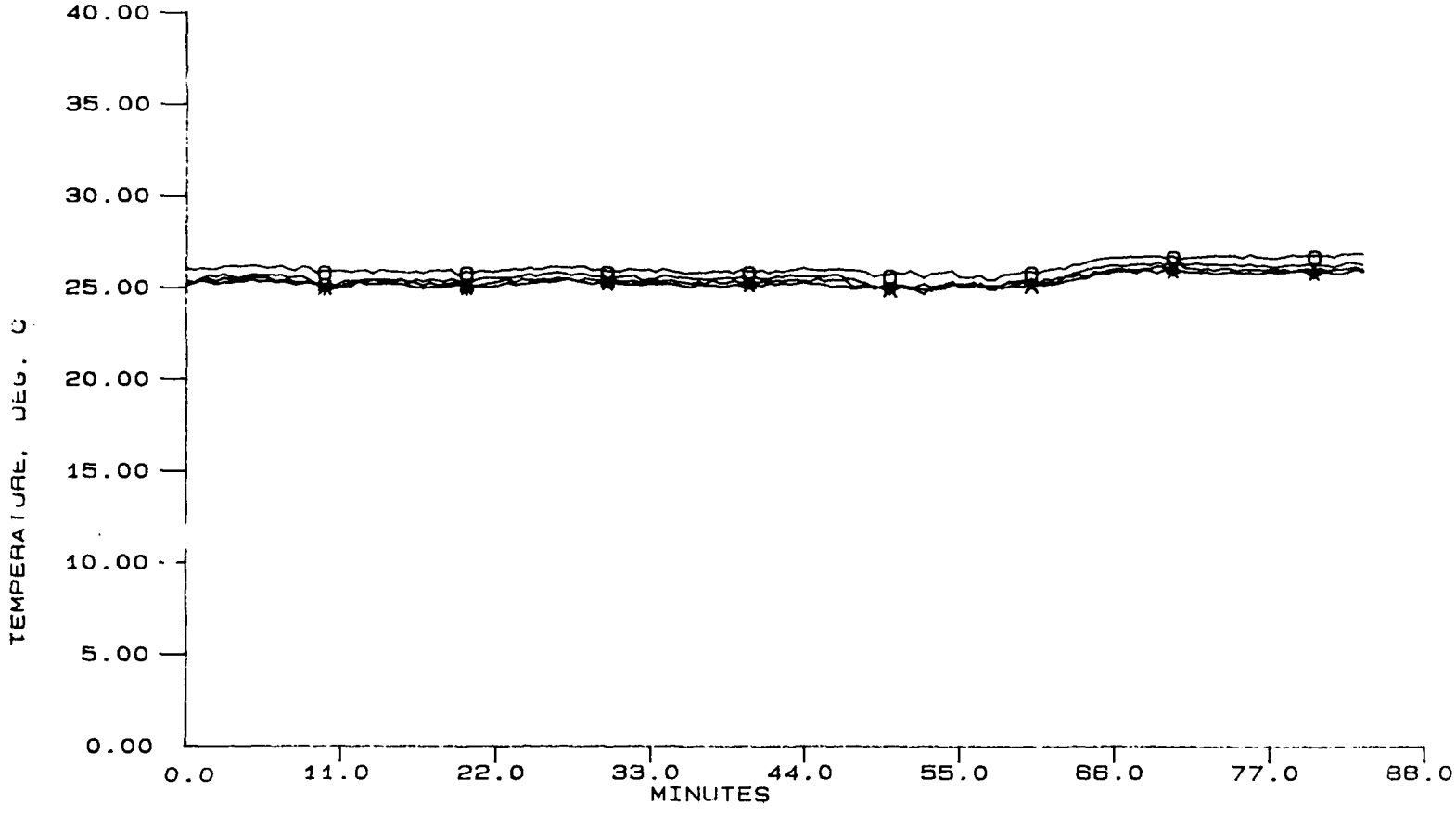
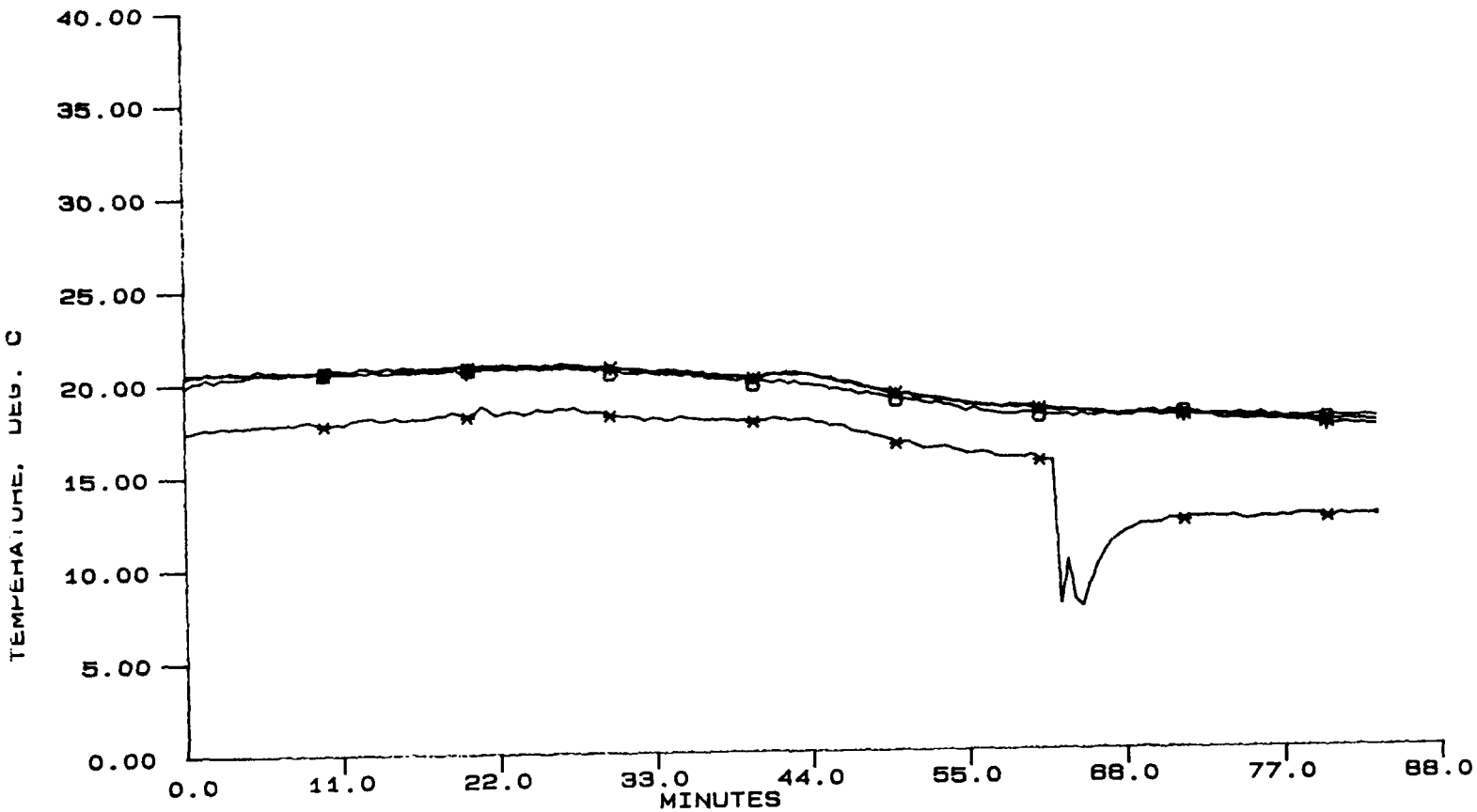


Fig. B-134 SMOKE CURTAIN TEST W-42 MAIN DECK CH 100○, 101X, 102+, 103✳



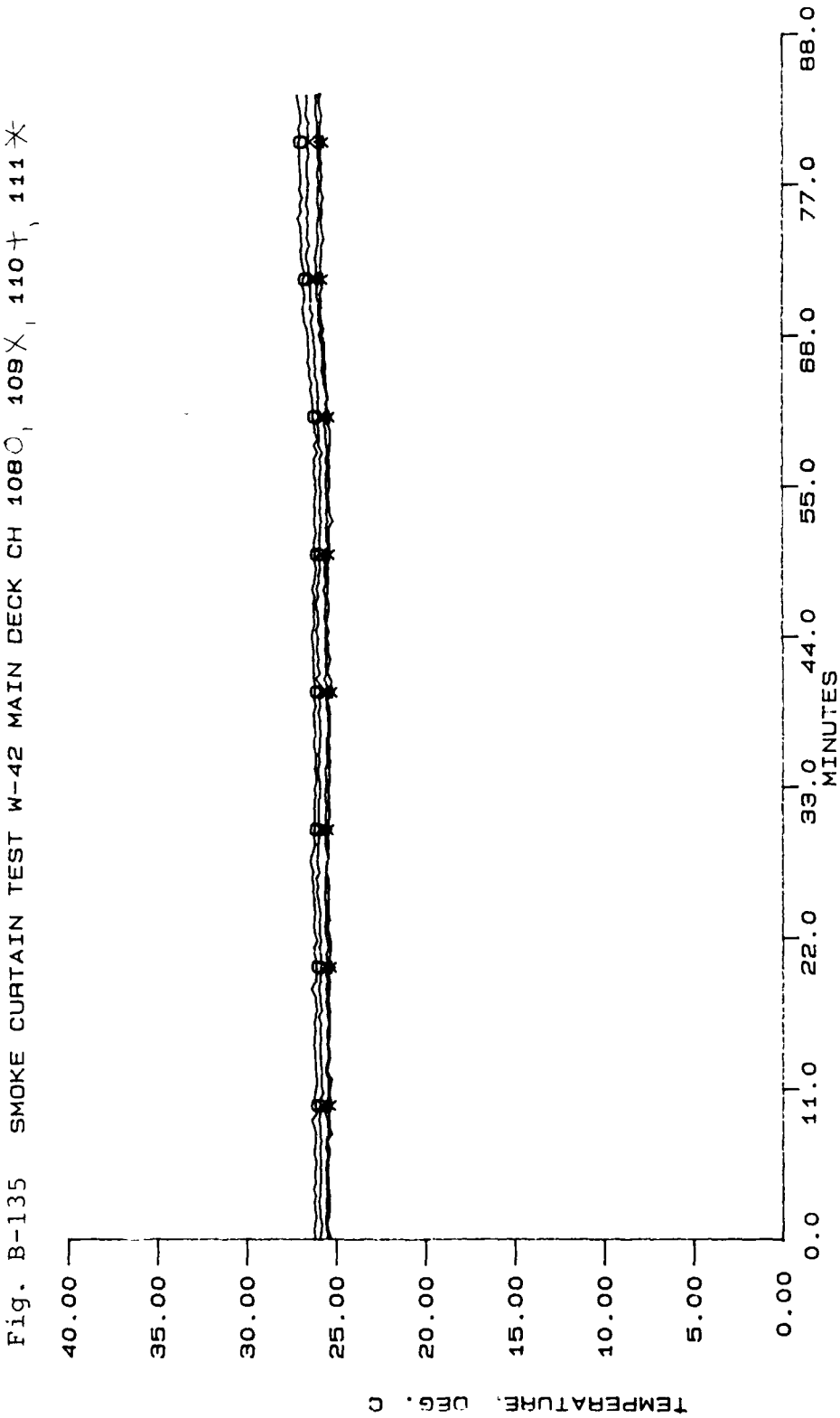


Fig. B-135 SMOKE CURTAIN TEST W-42 MAIN DECK CH 108○, 109×, 110+, 111✳
TEMPERATURE, DEG. C
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.0
11.0
22.0
33.0
44.0
55.0
66.0
77.0
88.0
MINUTES

Fig. B-136 SMOKE CURTAIN TEST W-42 MAIN DECK CH 94 ○, 98 X

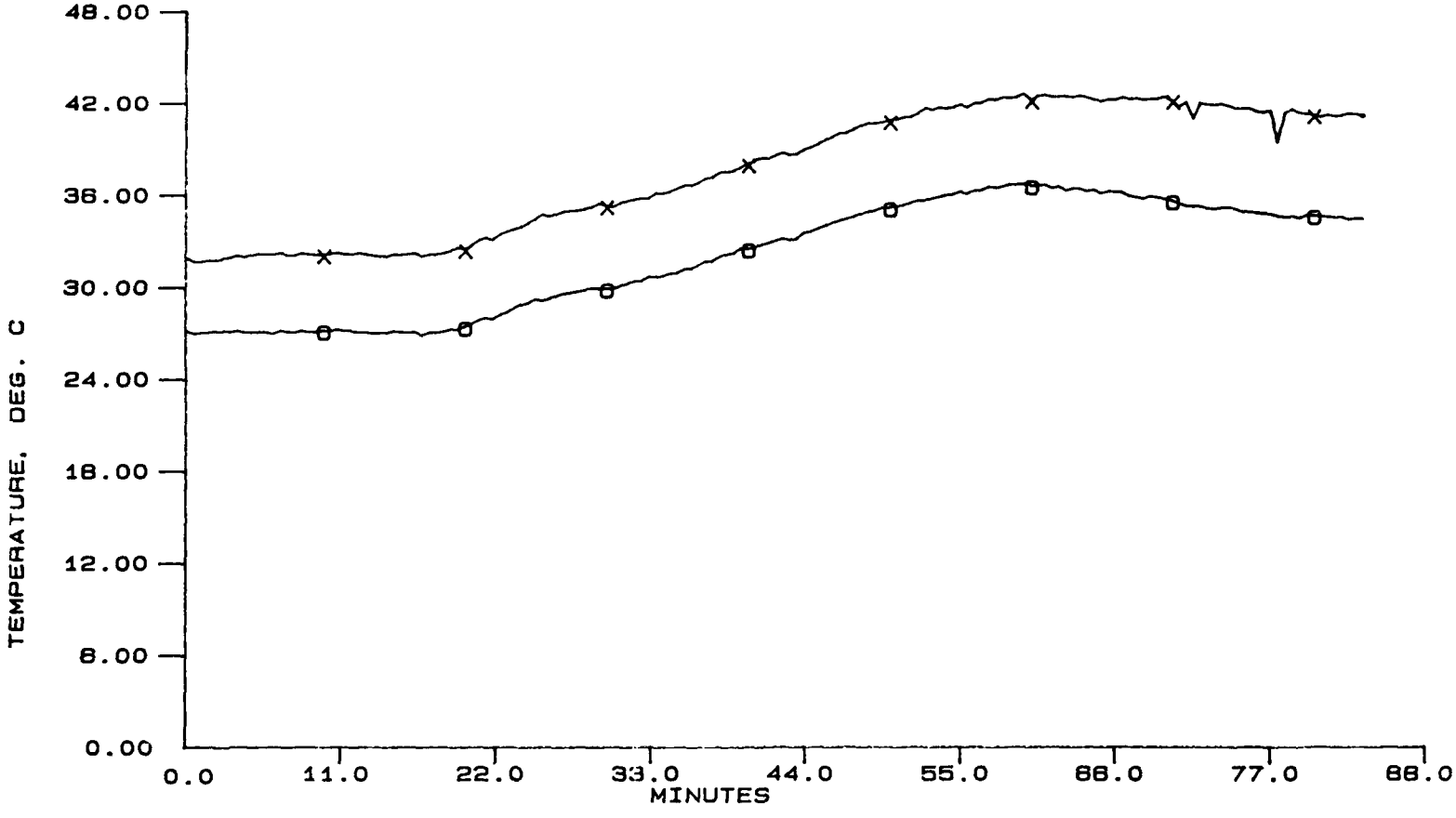


Fig. B-137 SMOKE CURTAIN TEST W-43 LEVEL 02 CH 116 ○, 117 X, 118 +, 119 ✳

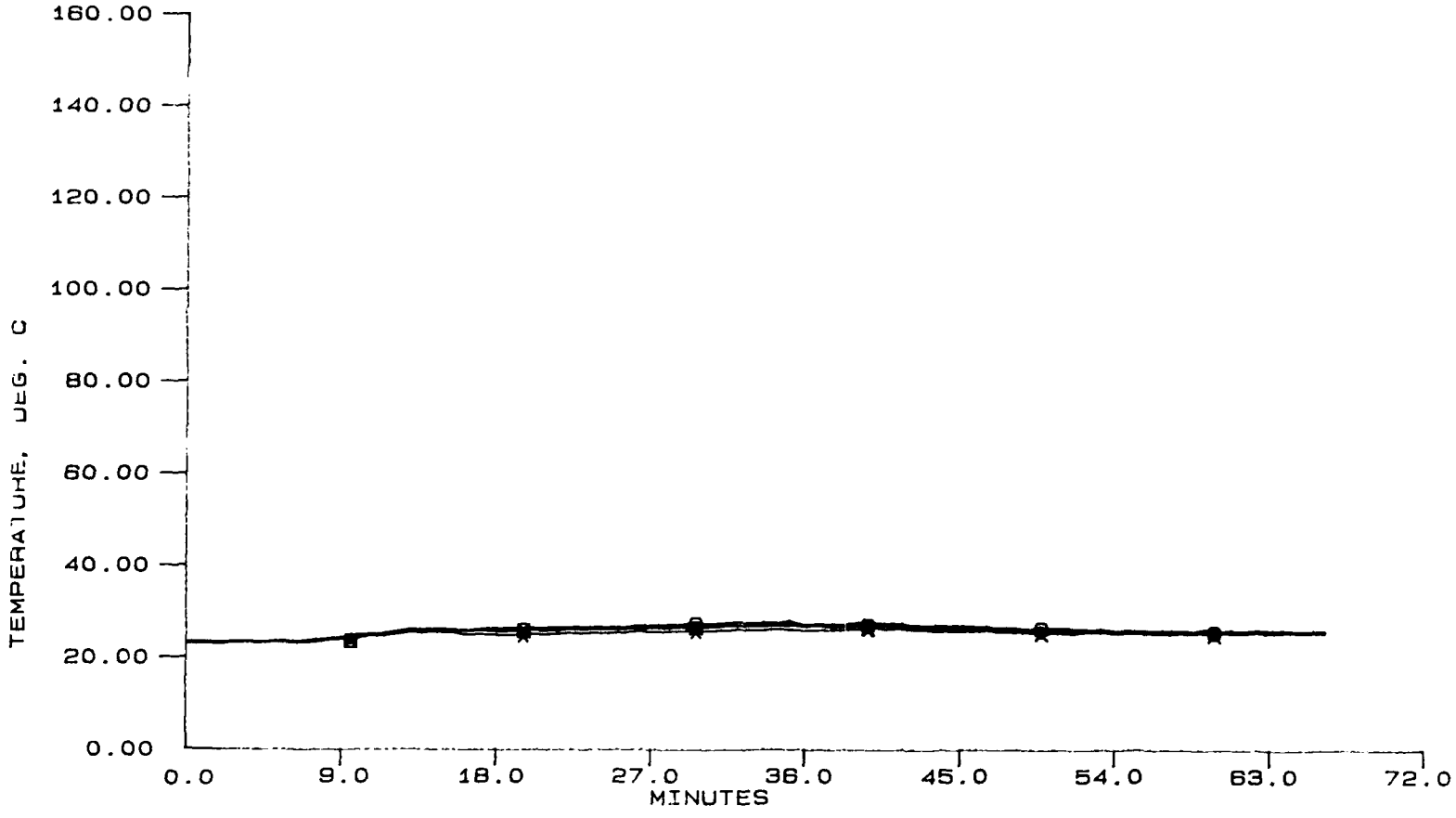


Fig. B-138 SMOKE CURTAIN TEST W-43 LEVEL 02 CH 56 ○, 57 X, 58 +, 59 ✳

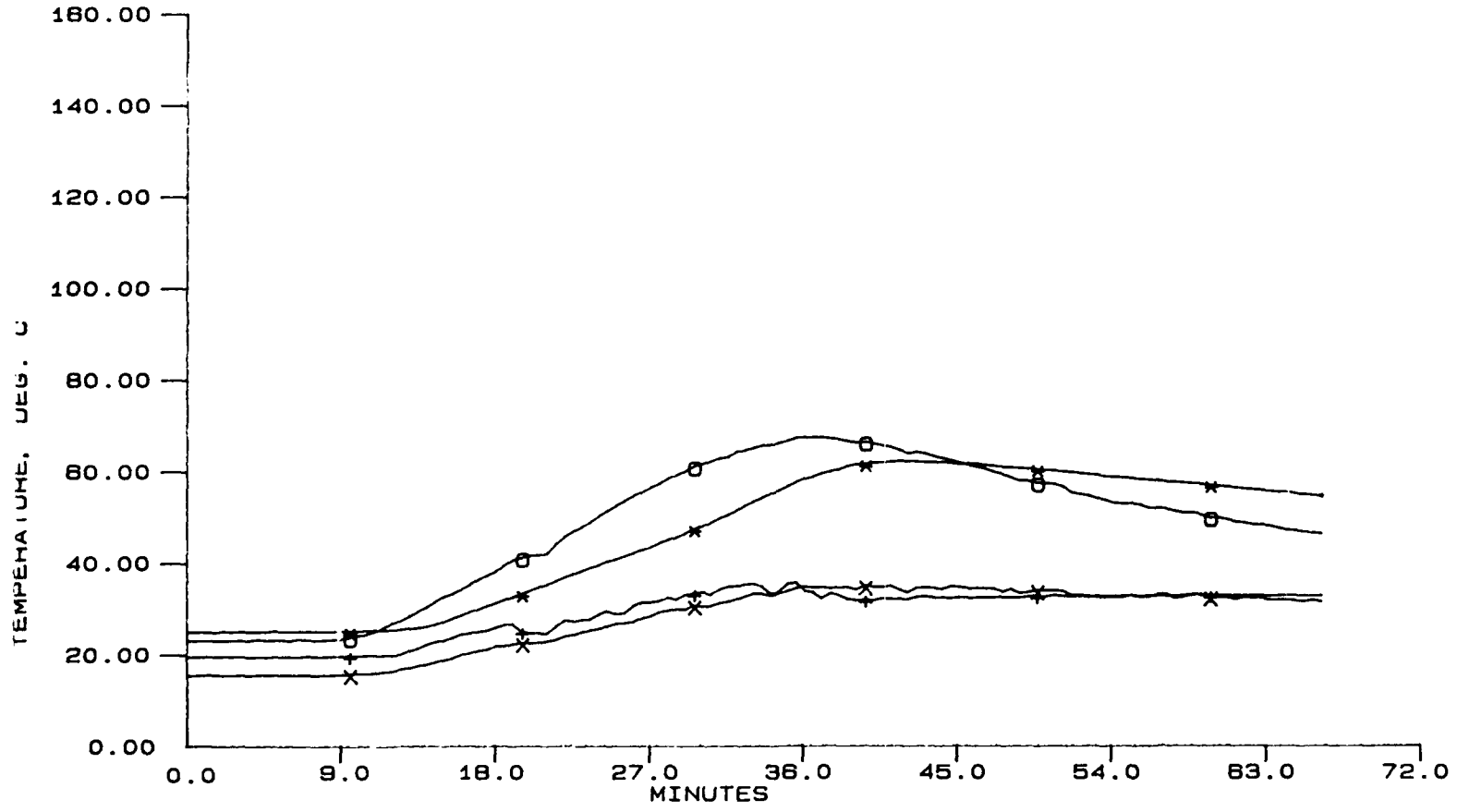


Fig. B-139 SMOKE CURTAIN TEST W-43 LEVEL 02 CH 52 ○, 53 X, 54 +, 55 ✳

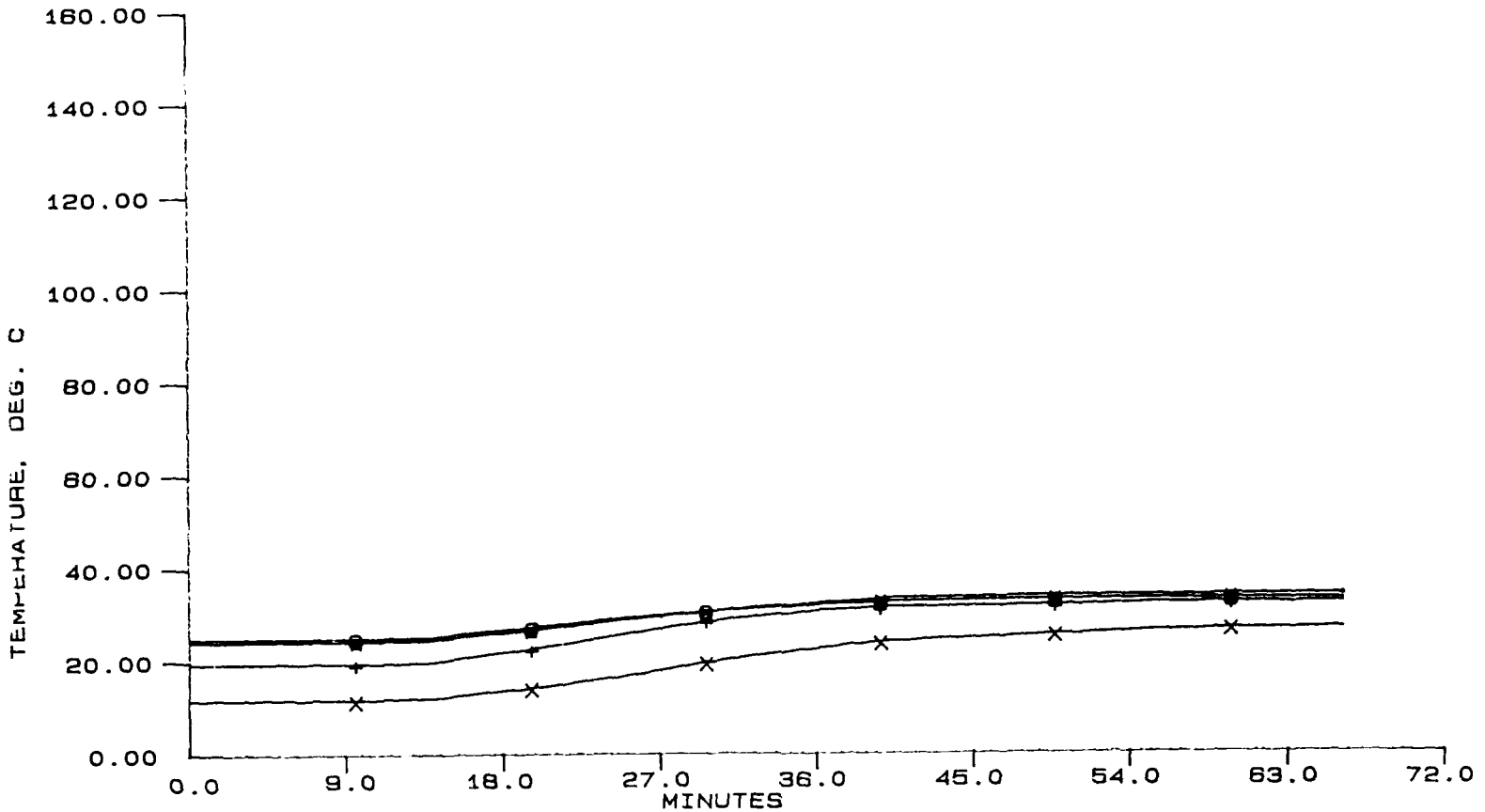


Fig. B-140 SMOKE CURTAIN TEST W-43 LEVEL 02 CH 48 O, 49 X, 50 +, 51 ✳

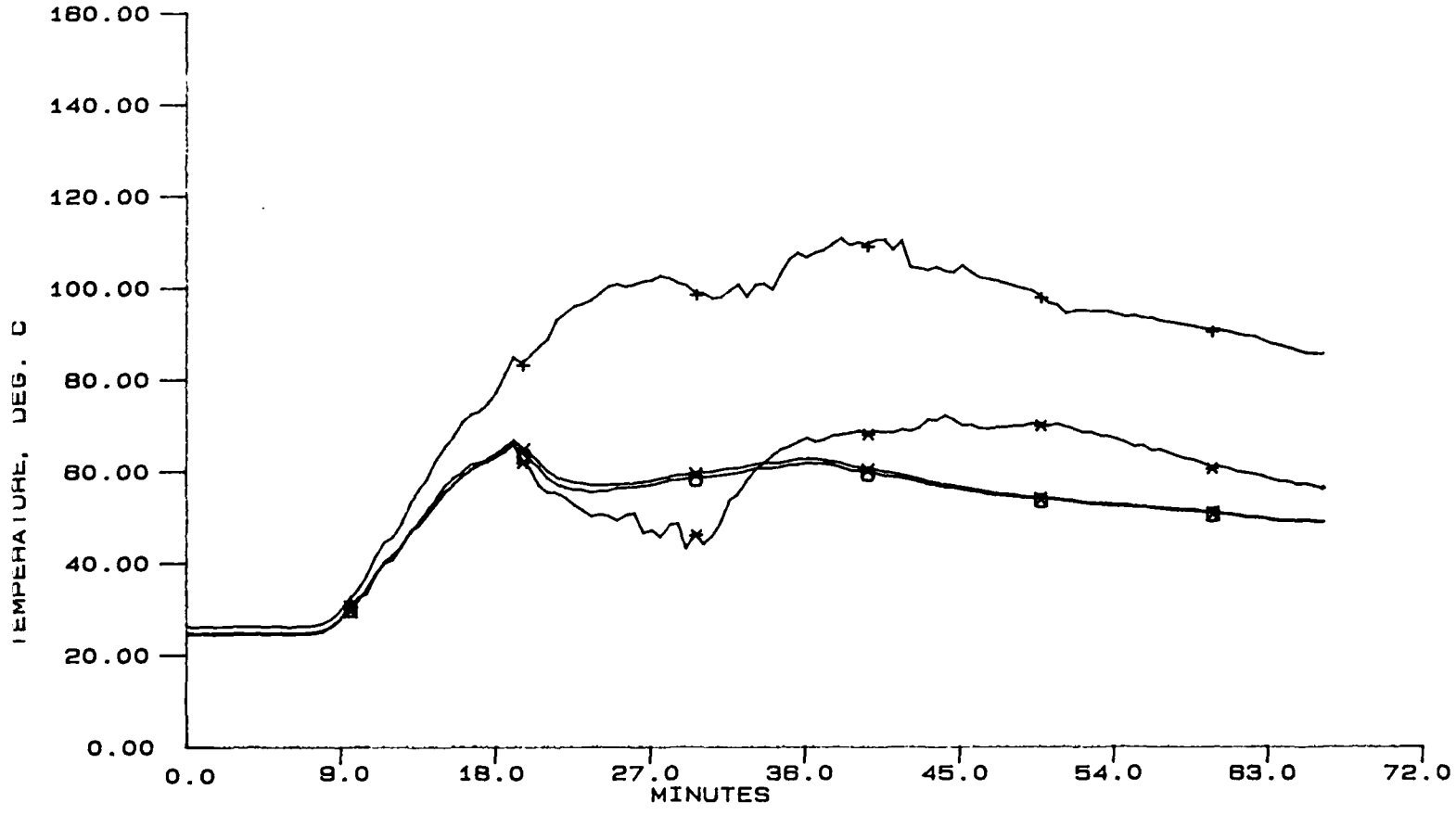


Fig. B-141 SMOKE CURTAIN TEST W-43 LEVEL 02 CH 44 O, 45 X, 46 +, 47 *

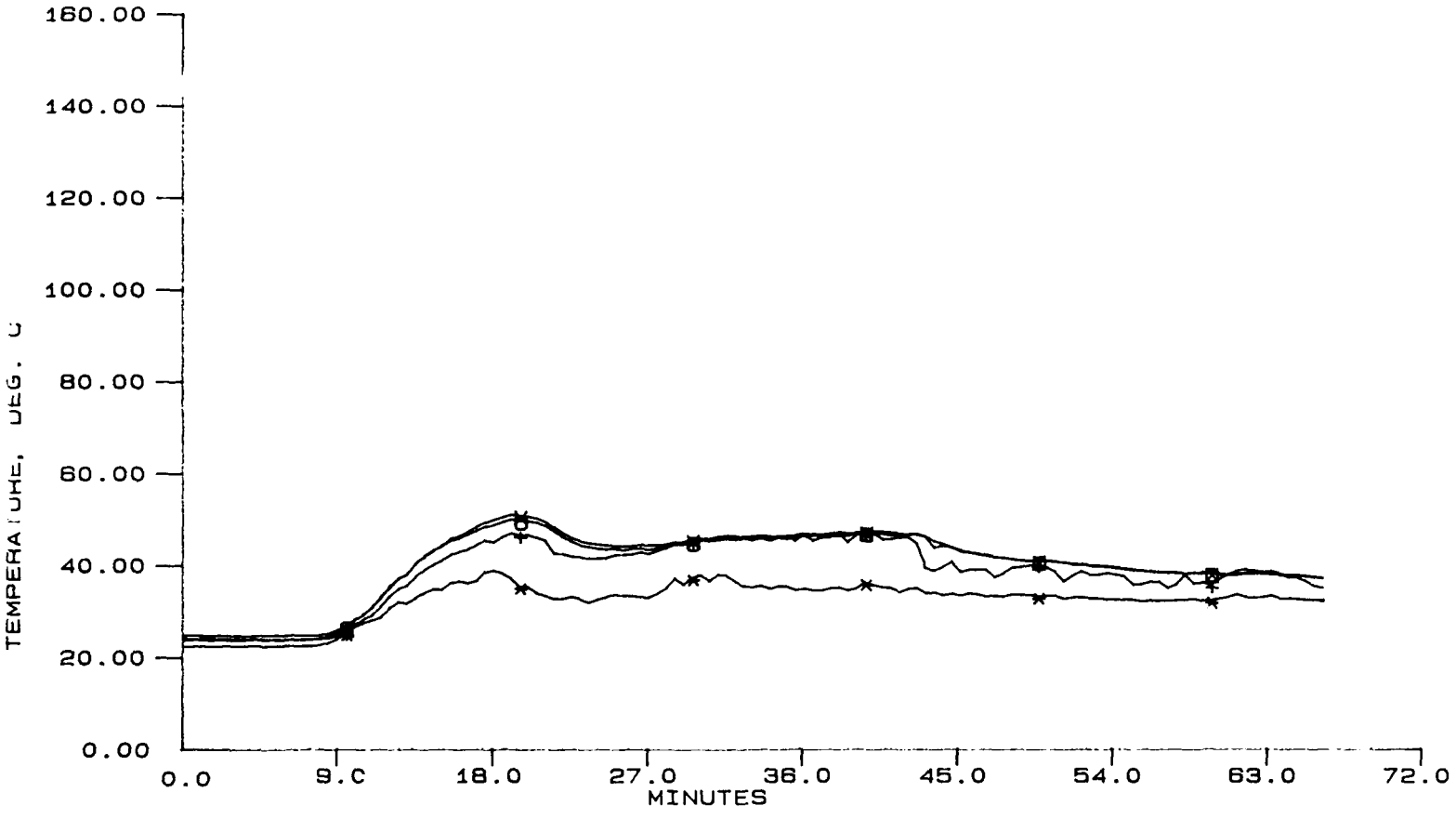


Fig. B-142 SMOKE CURTAIN TEST W-43 LEVEL 01 CH 72 ○, 73 X, 74 + 75, ✳

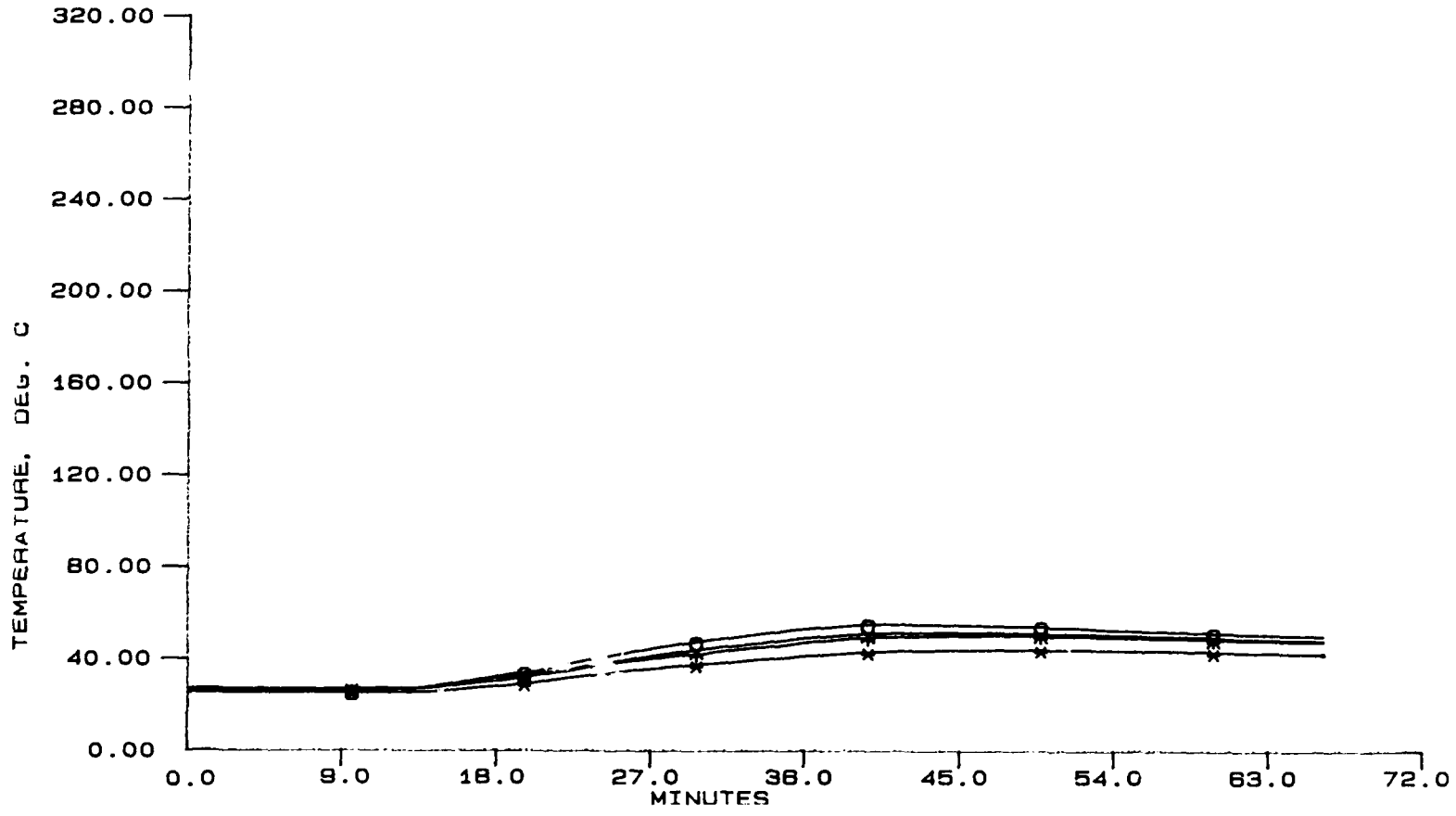


Fig. B-143 SMOKE CURTAIN TEST W-43 LEVEL 01 CH 64 O, 65 X, 66 +, 67 ✳

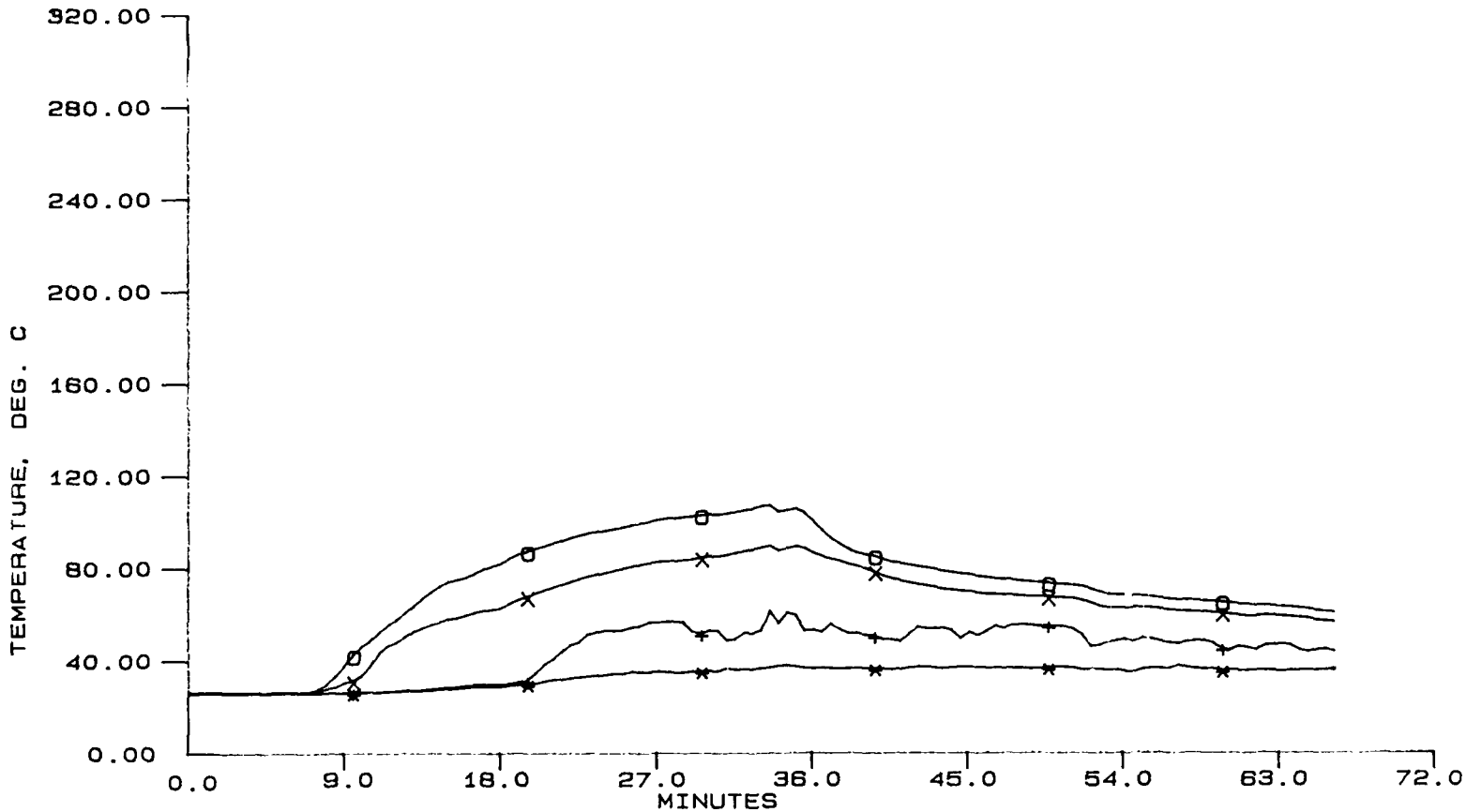


Fig. B-144 SMOKE CURTAIN TEST W-43 LEVEL 01 CH 60 O, 61 X, 62 +, 63 ✳

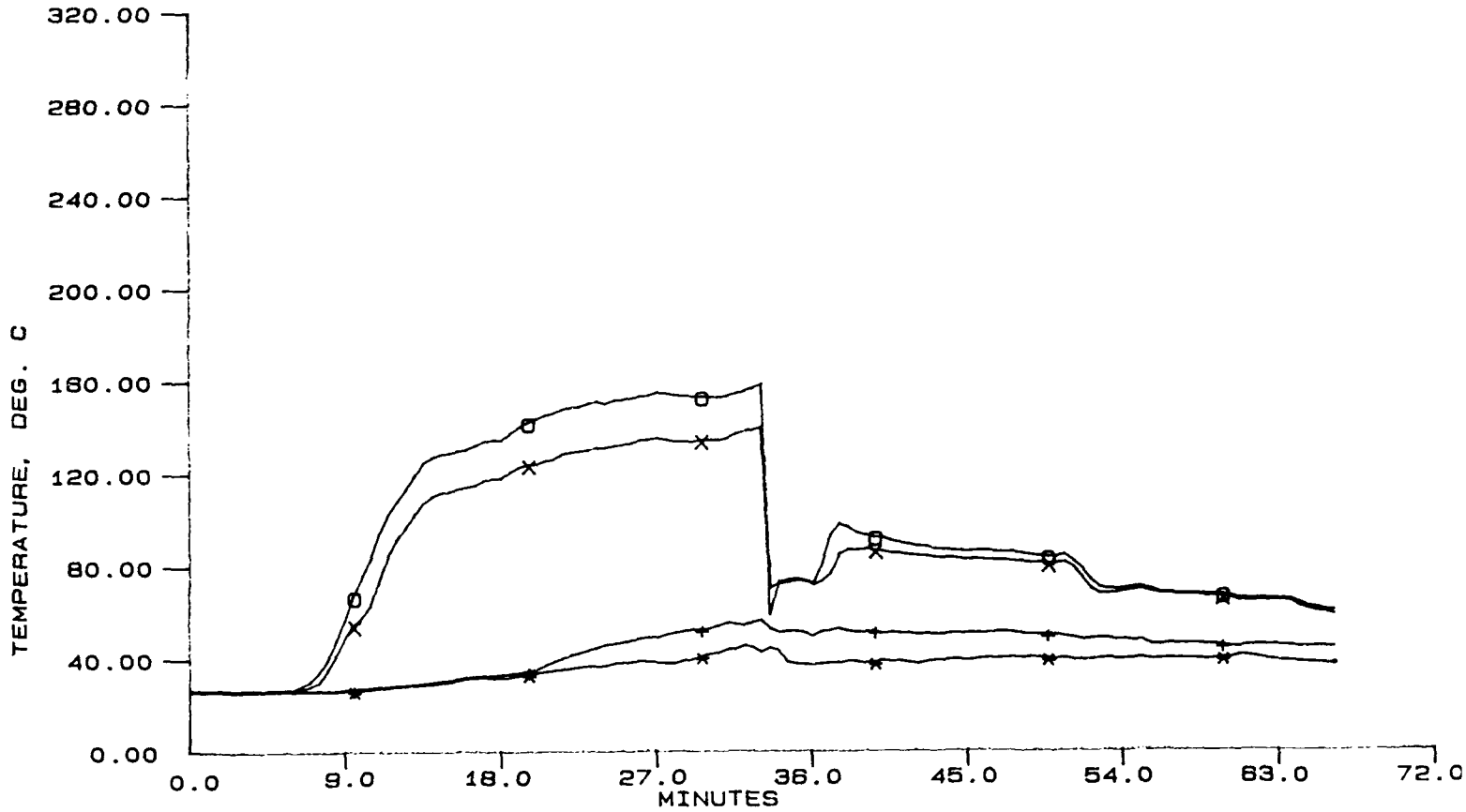


Fig. B-145 SMOKE CURTAIN TEST W-43 LEVEL 01 CH 68 O, 69 X, 70 +, 71 ✳

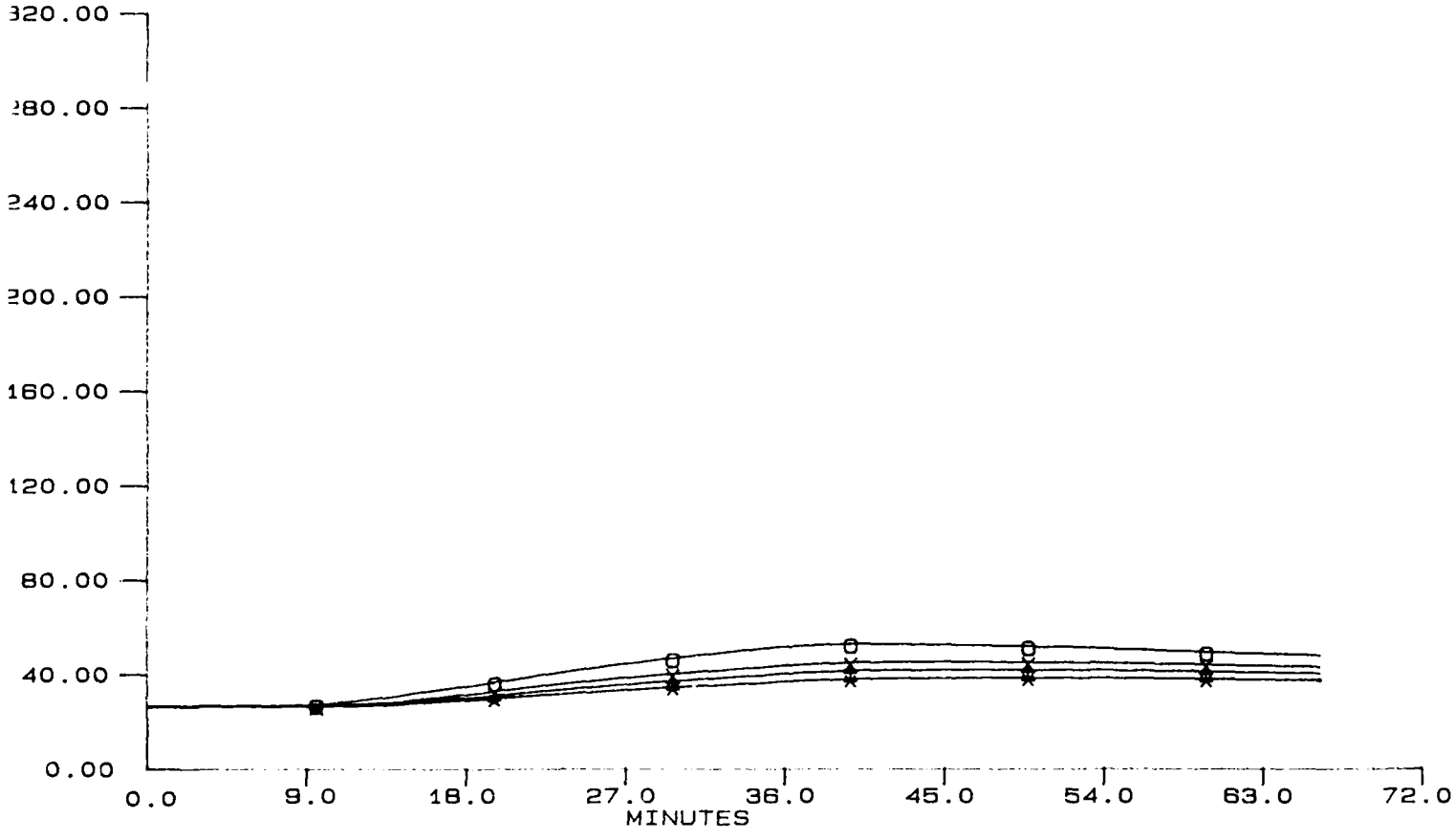


Fig. B-146 SMOKE CURTAIN TEST W-43 LEVEL 01 CH 112 ○, 113 X, 114 +, 115 ✳

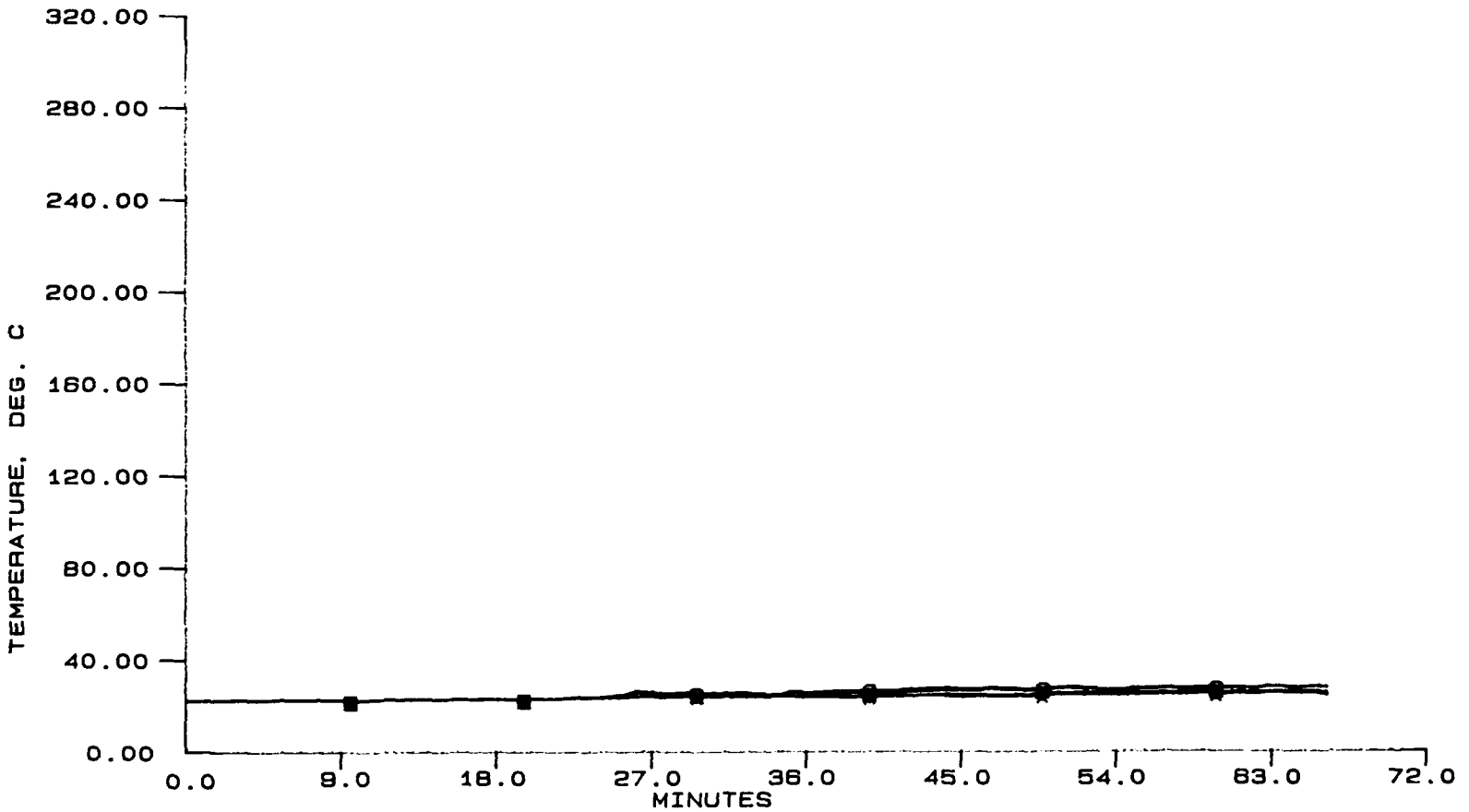


Fig. B-147 SMOKE CURTAIN TEST W-43 LEVEL 01 CH 78 ○, 77 X, 78 +, 78 ✳

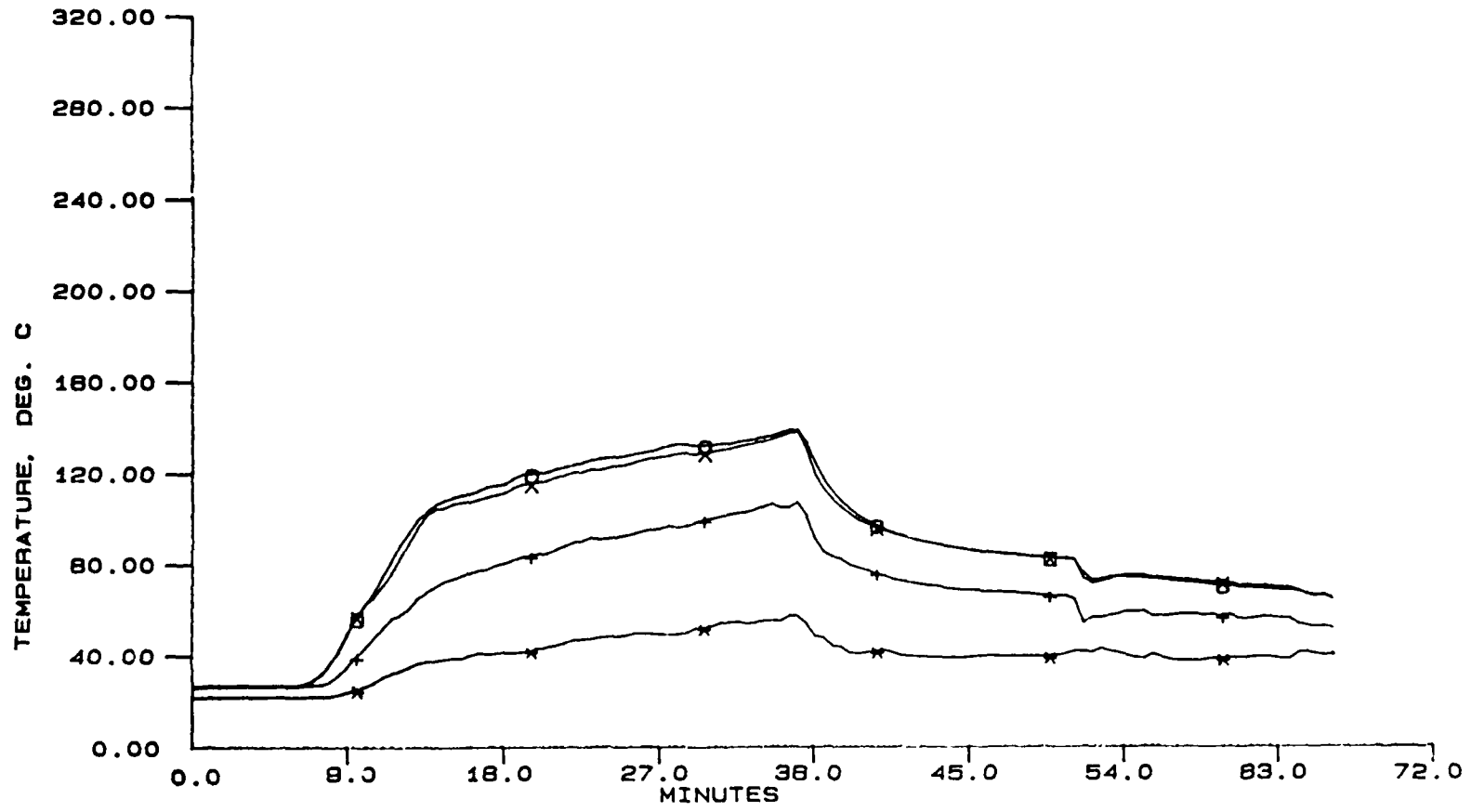


Fig. B-148 SMOKE CURTAIN TEST W-43 LEVEL 01 CH 80 ○, 81 ×, 82 +, 83 ✳

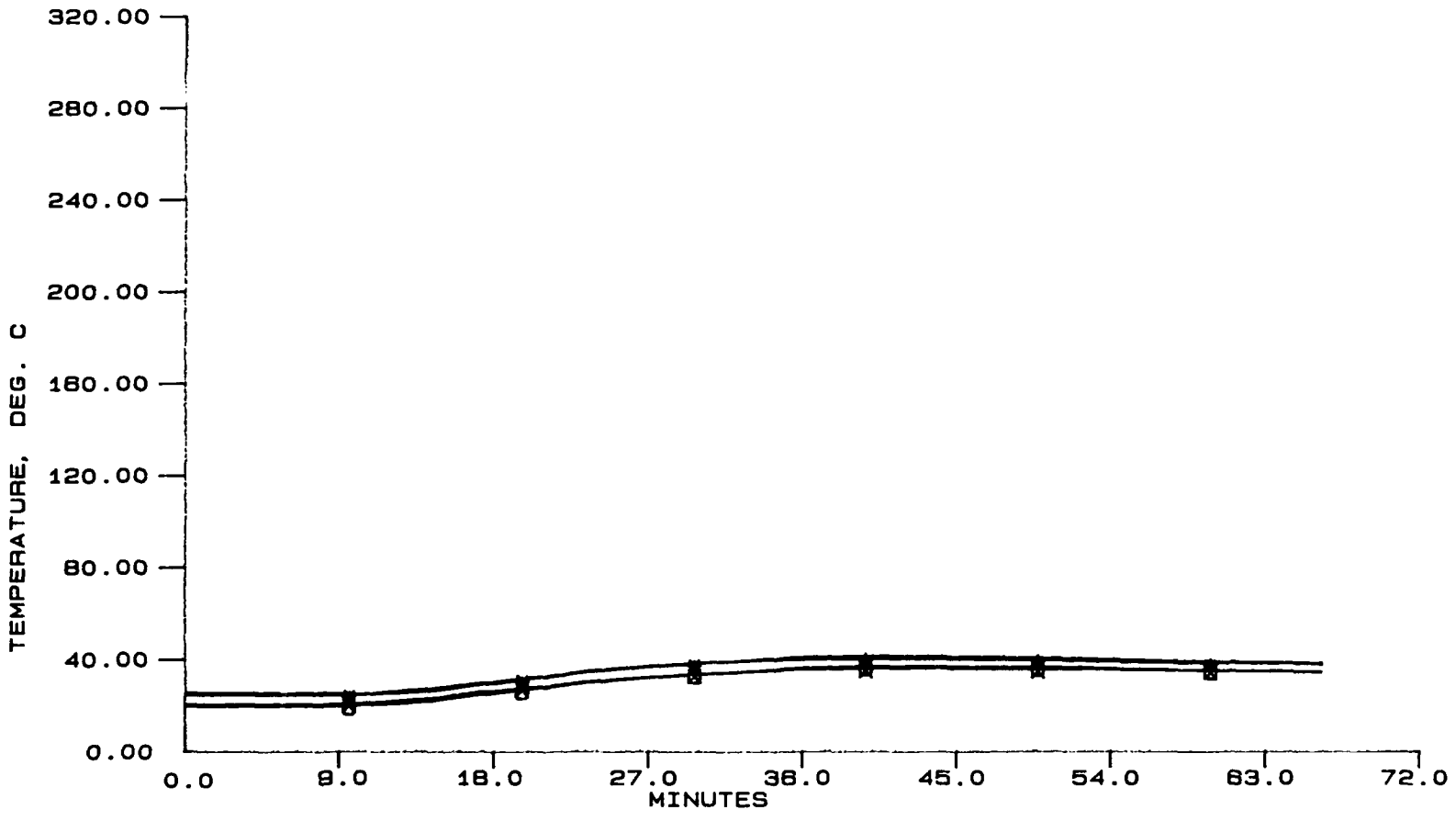


Fig. B-149 SMOKE CURTAIN TEST W-43 LEVEL 01 CH 84 O, 85 X, 86 +, 87 X

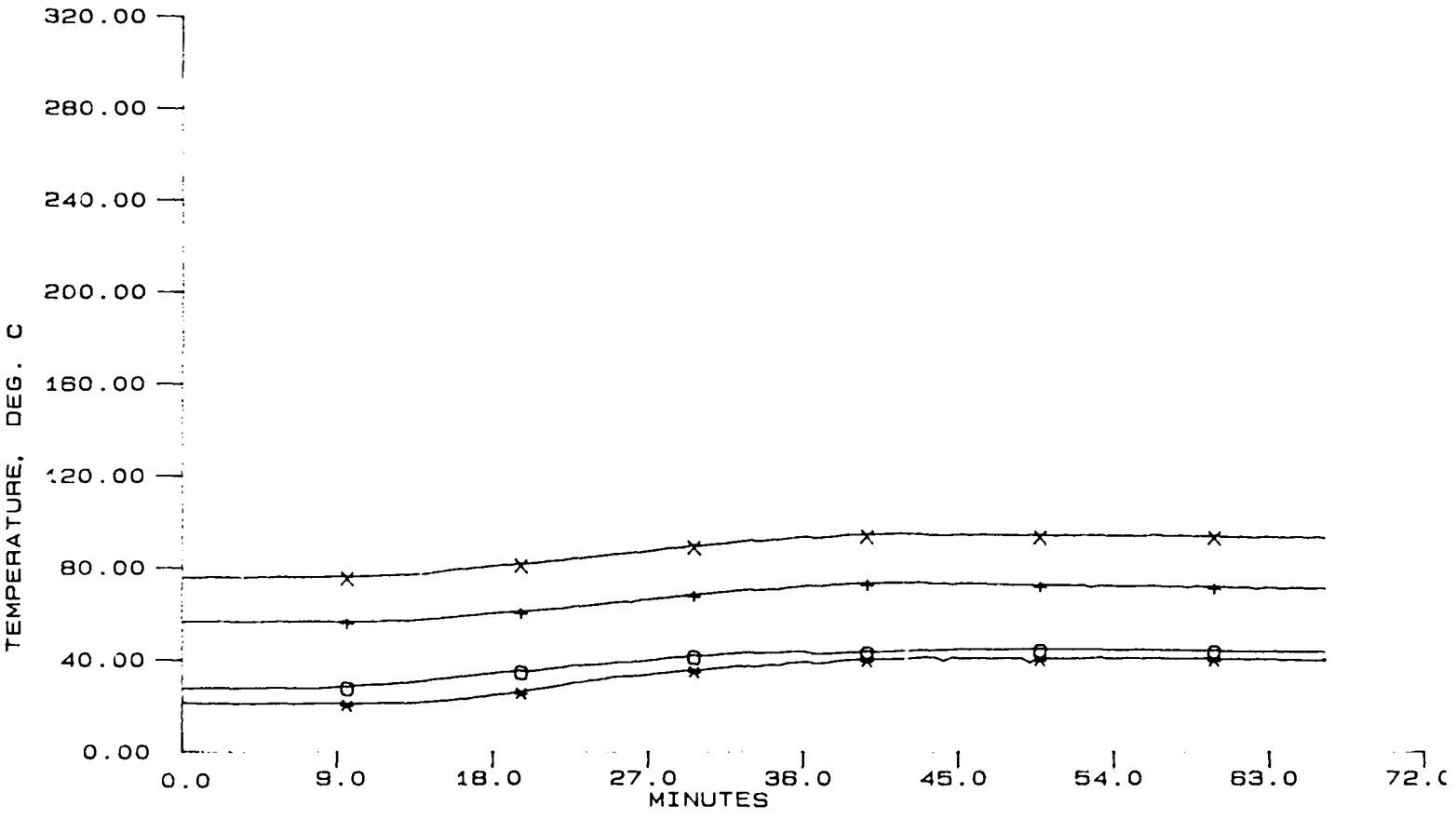


Fig. B-150 SMOKE CURTAIN TEST W-43 MAIN DECK CH 104 ○, 105 X, 106 +, 107 ✳

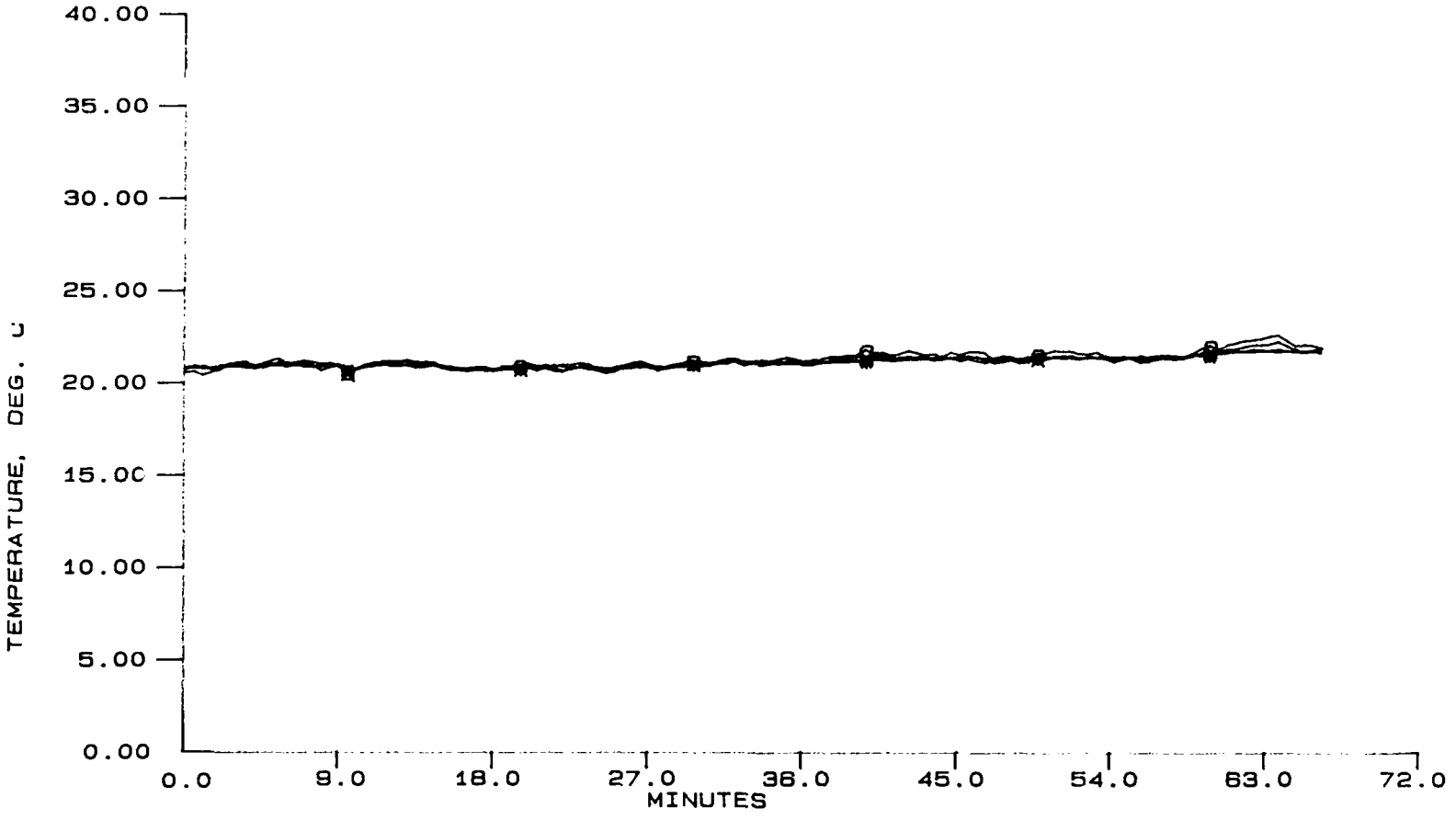


Fig. B-151 SMOKE CURTAIN TEST W-43 MAIN DECK CH 100 O, 101 X, 102 +, 103 ✳

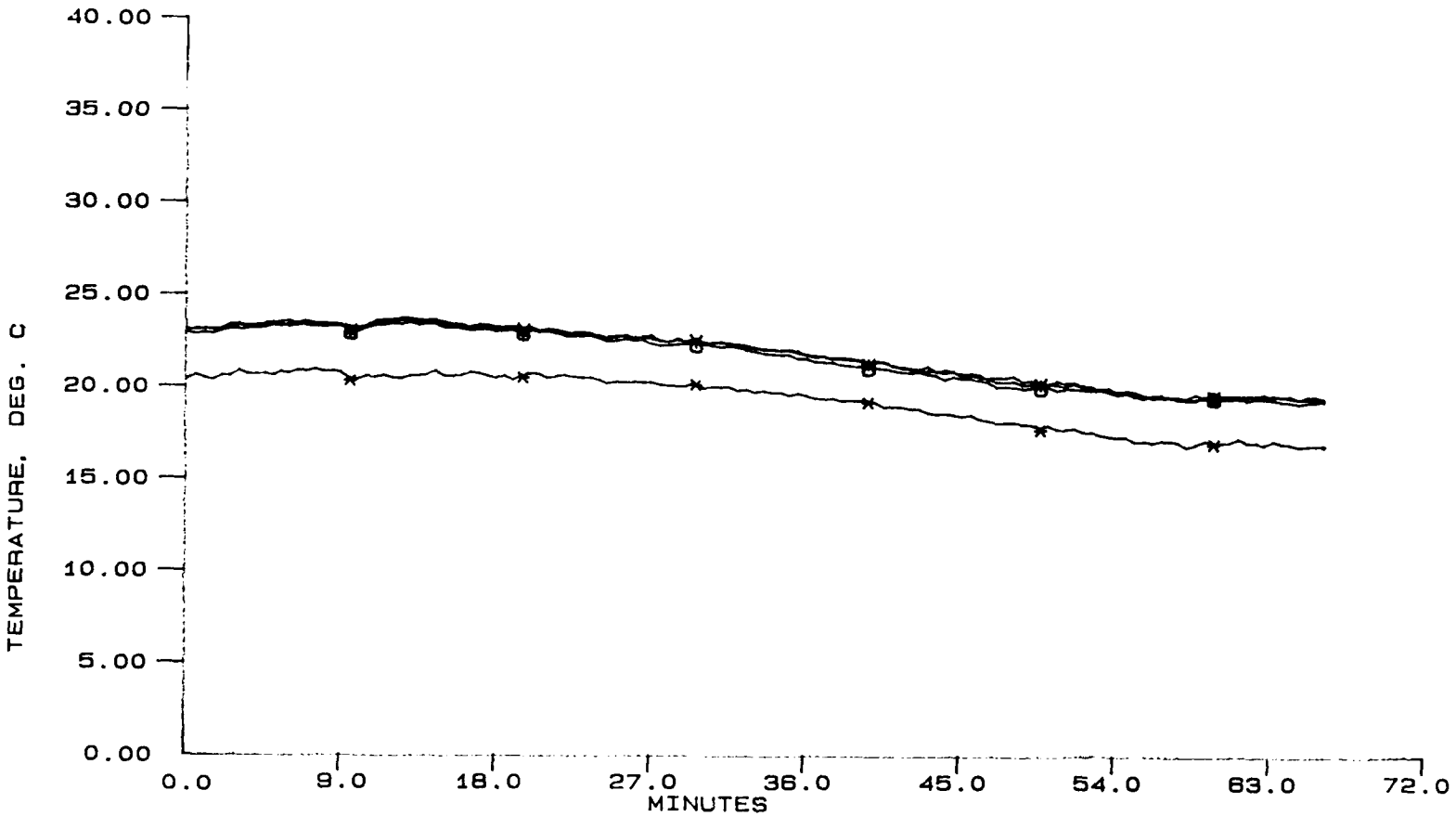


Fig. B-152 SMOKE CURTAIN TEST W-43 MAIN DECK CH 108 ○, 109 X, 110 +, 111 ✳

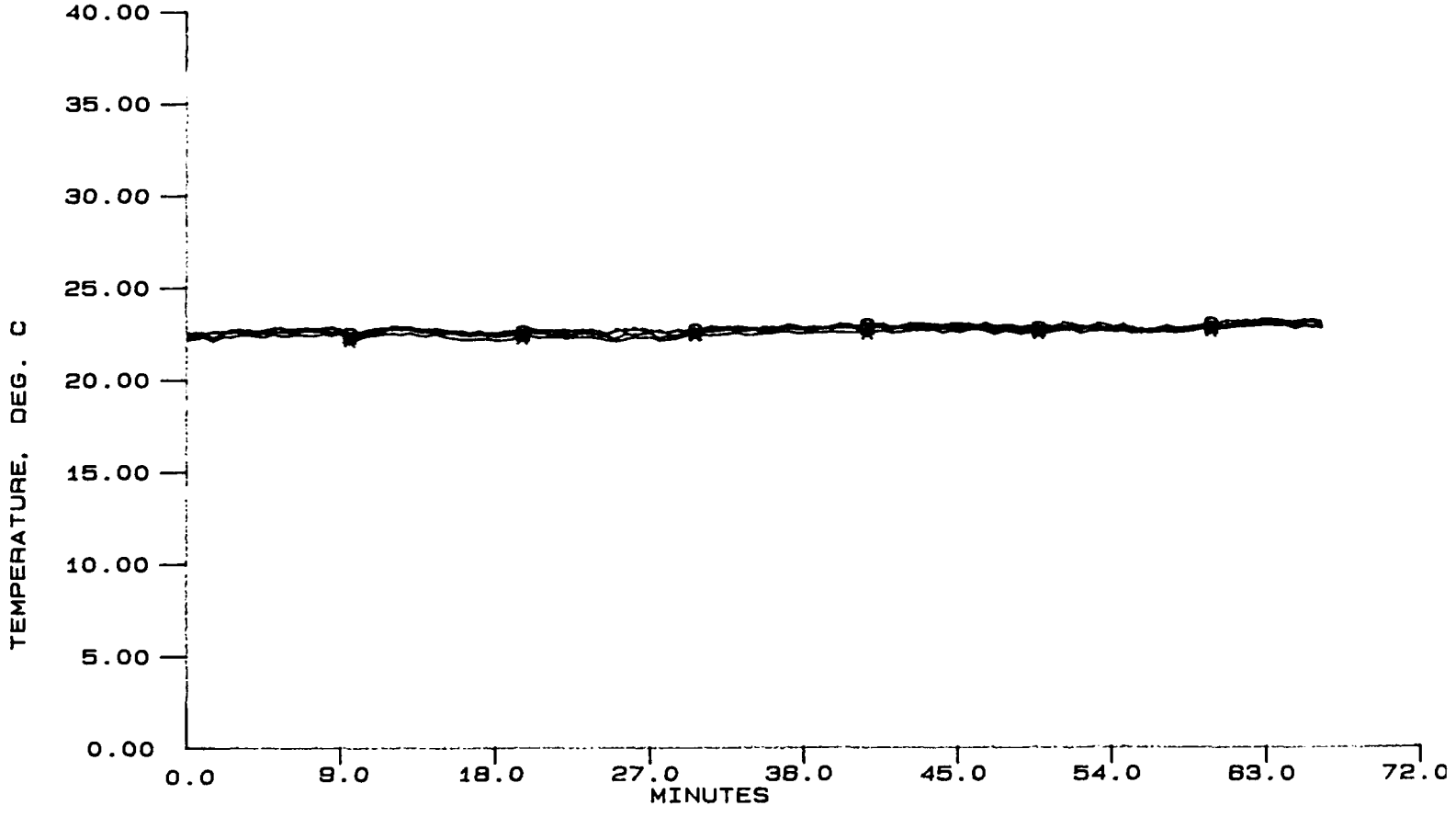


Fig. B-153 SMOKE CURTAIN TEST W-43 MAIN DECK CH 94 ○, 98 X

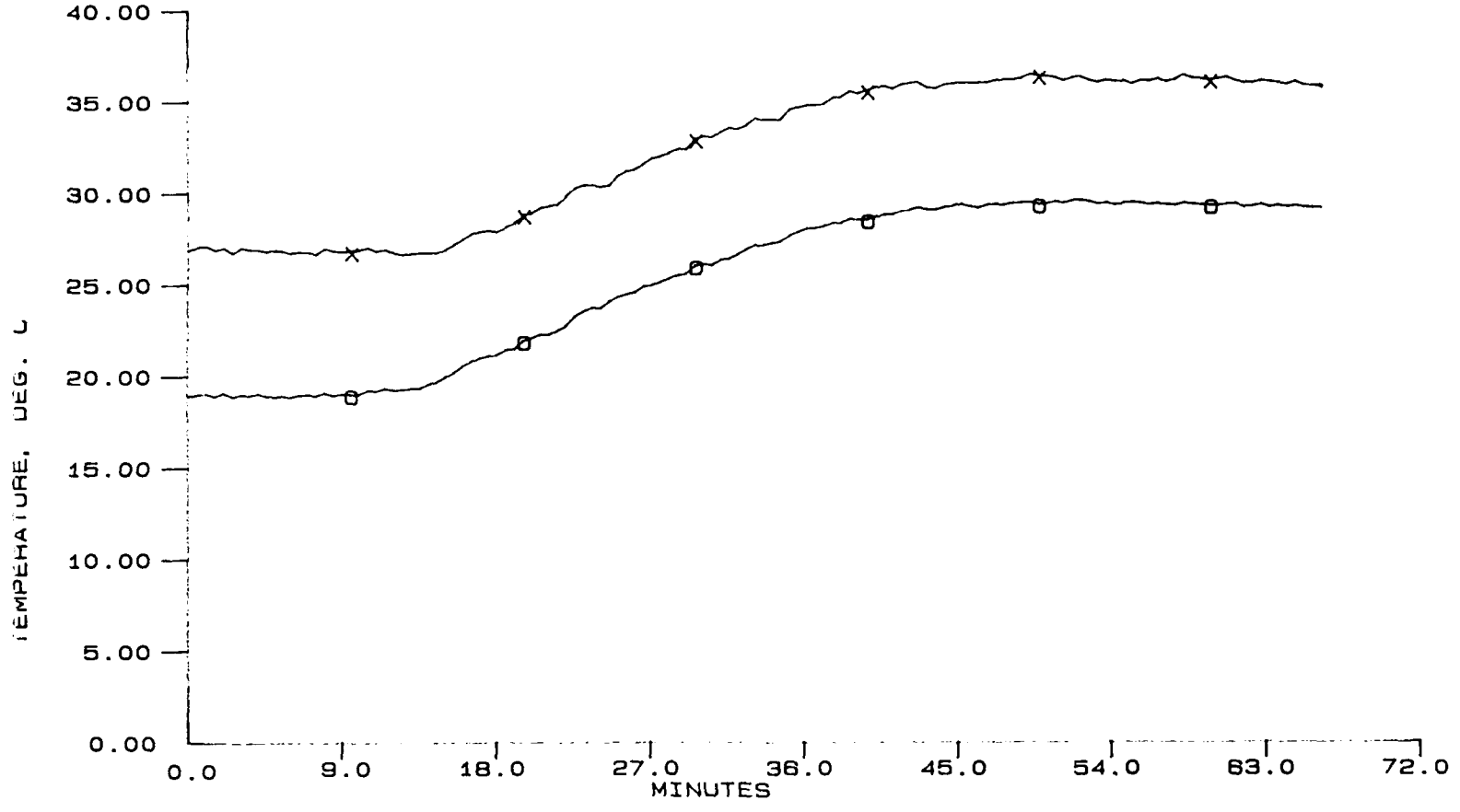


Fig. B-154 SMOKE CURTAIN TEST W-44 LEVEL 02 CH 116 ○, 117 X, 118 +, 119 ✳

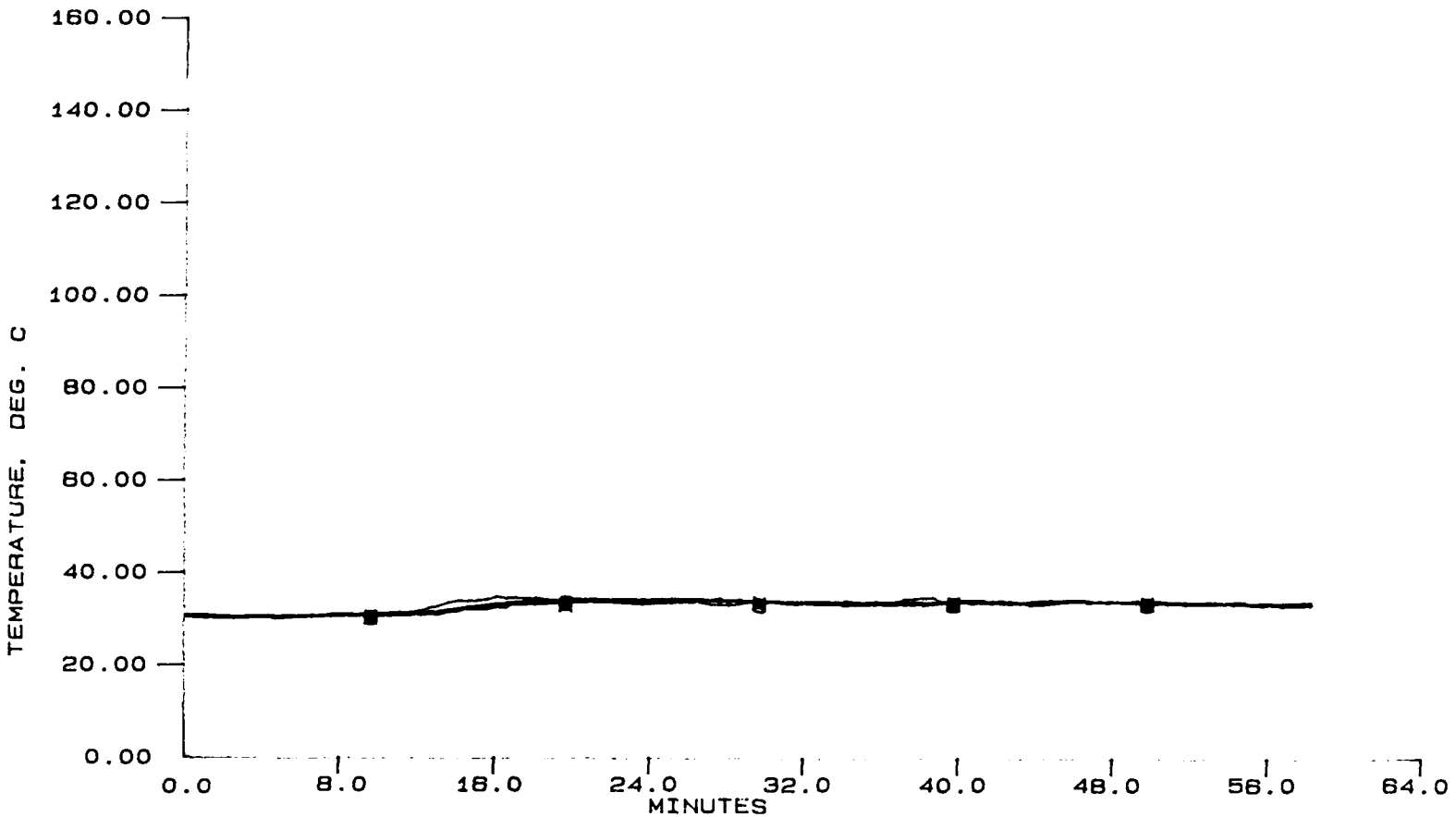


Fig. B-155 SMOKE CURTAIN TEST W-44 LEVEL 02 CH 58 ○, 57 X, 58 +, 59 ✳

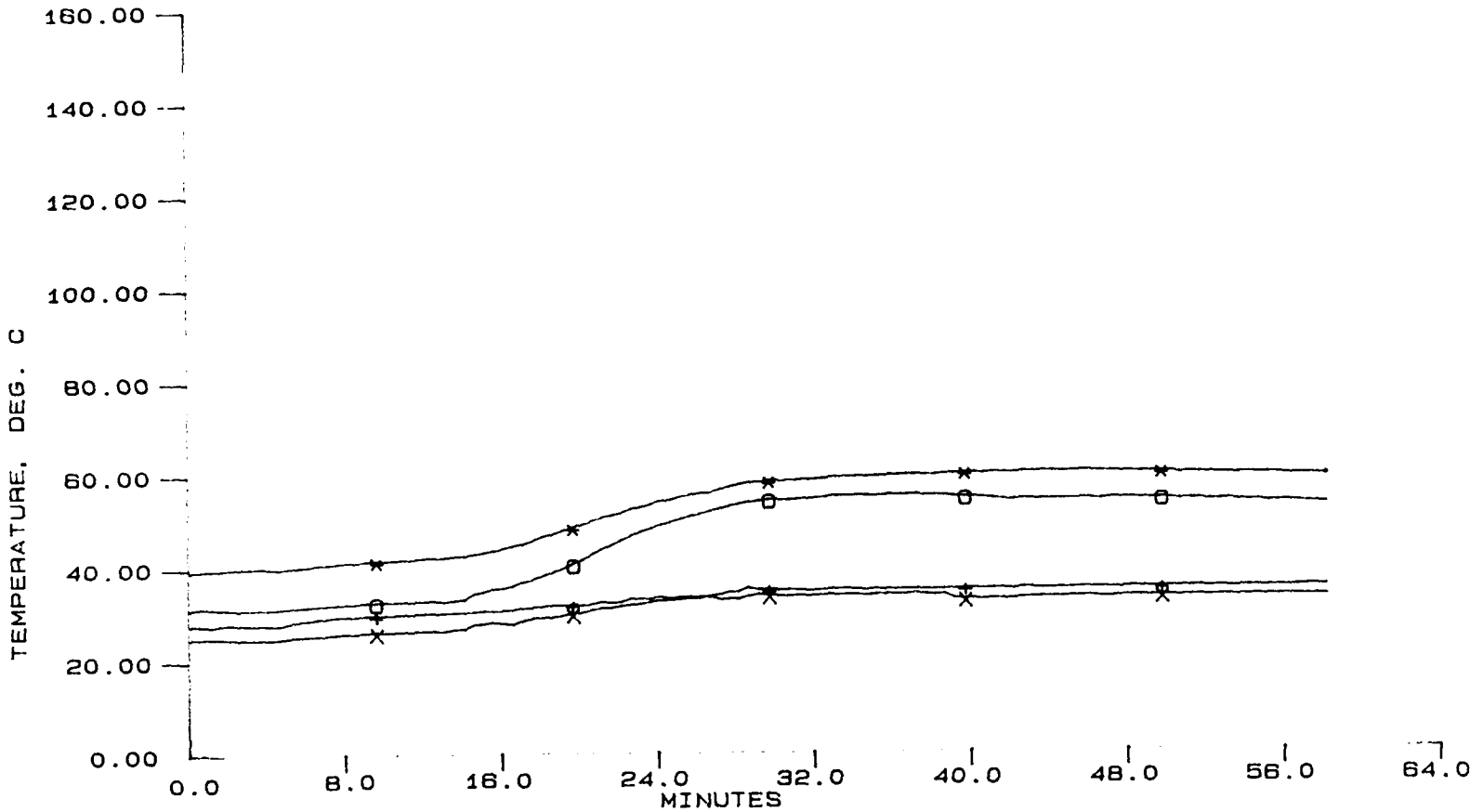


Fig. B-156 SMOKE CURTAIN TEST W-44 LEVEL 02 CH 52 ○, 53 X, 54 +, 55 ✳

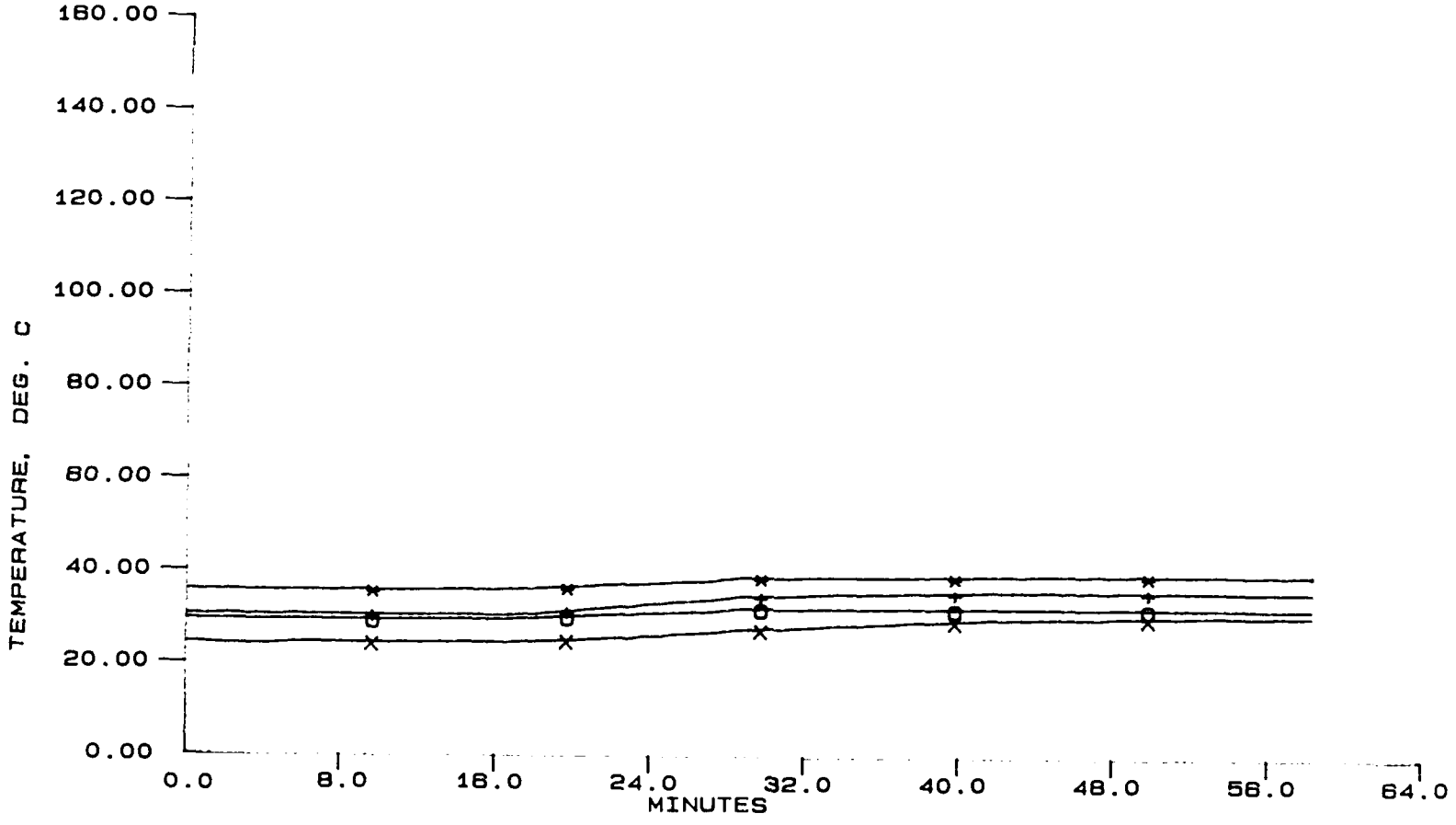


Fig. B-157 SMOKE CURTAIN TEST W-44 LEVEL 02 CH 48 ○, 49 X, 50 +, 51 ✳

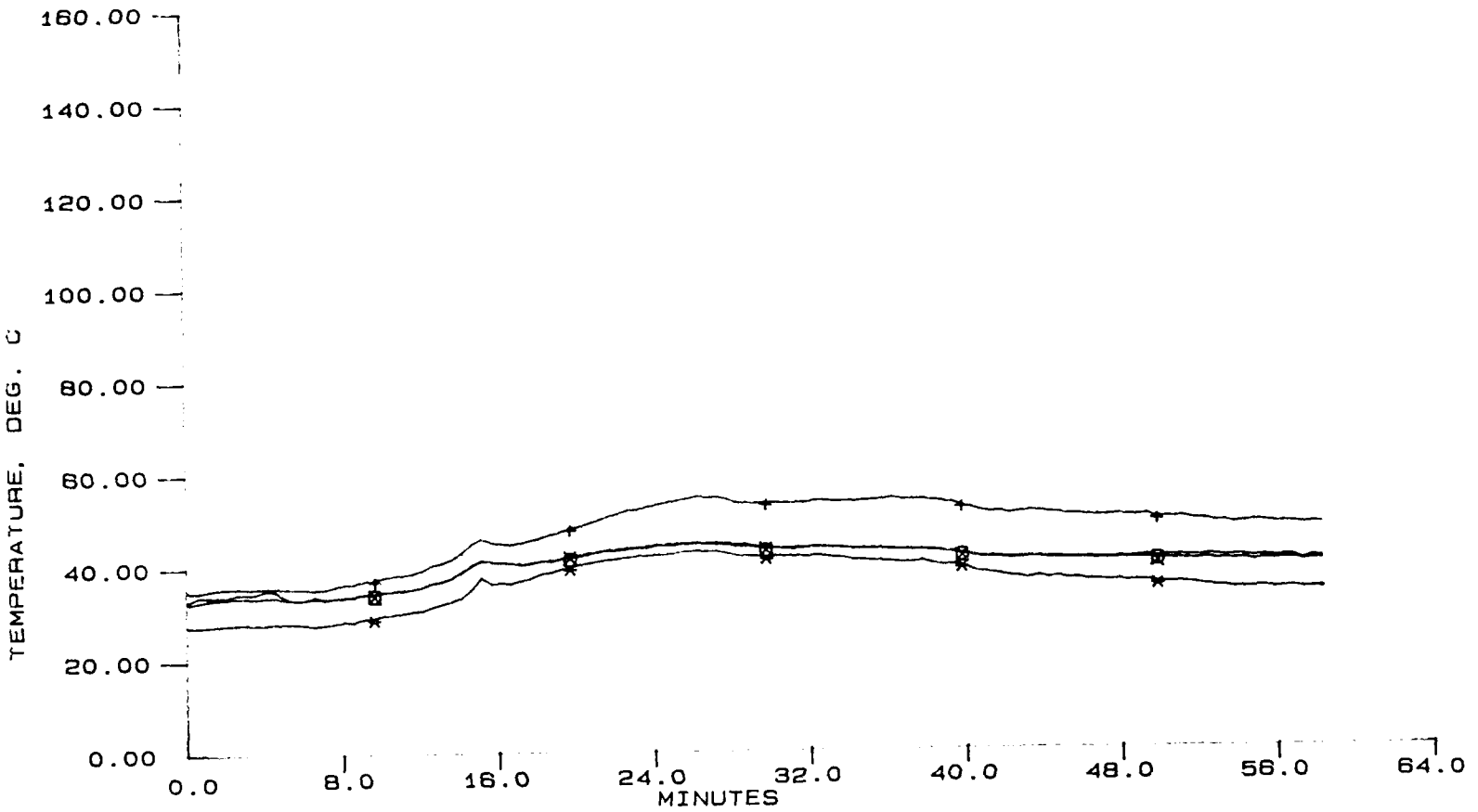


Fig. B-158 SMOKE CURTAIN TEST W-44 LEVEL 02 CH 44 ○, 45 X, 46 +, 47 ✳

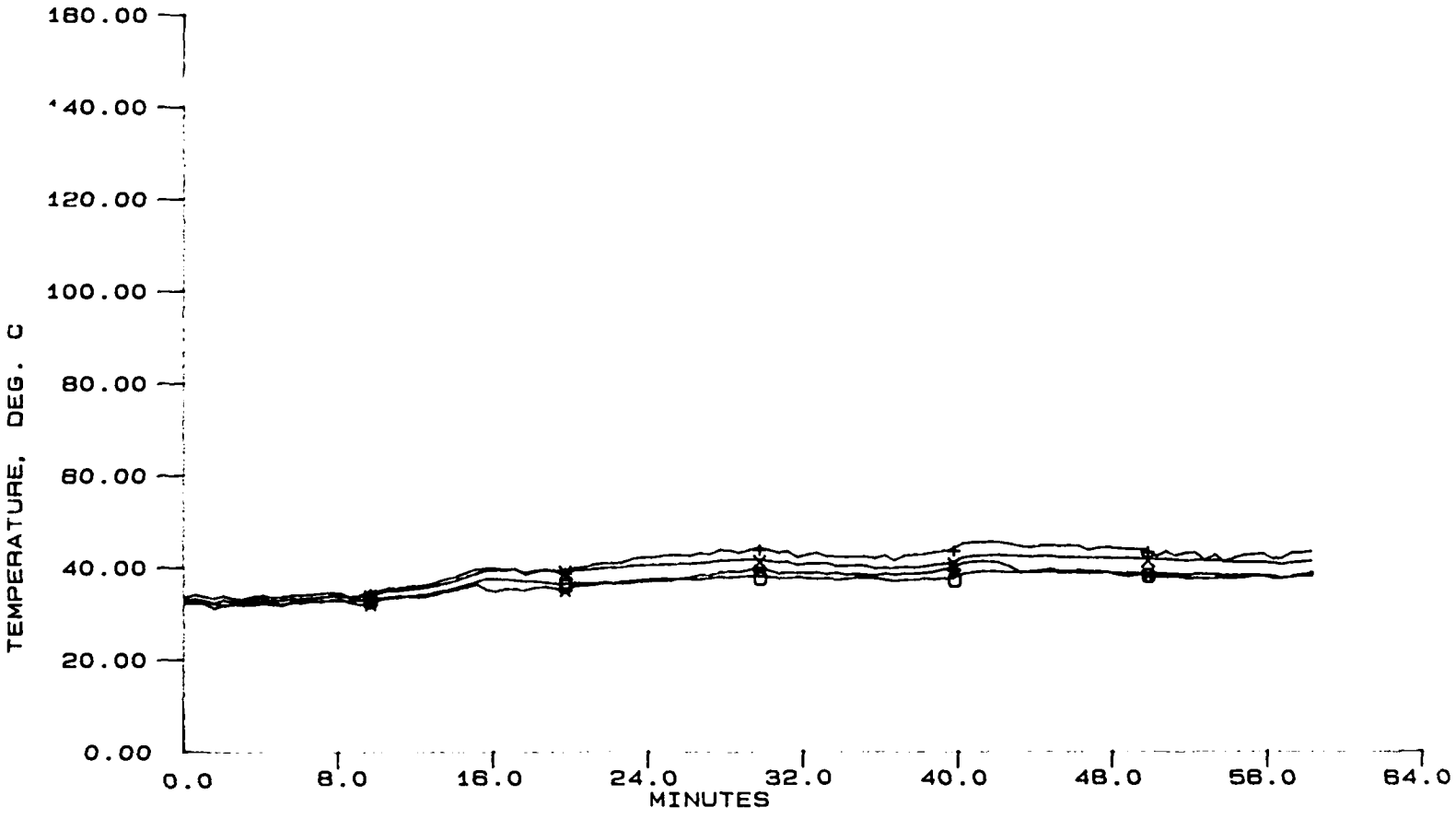


Fig. B-159 SMOKE CURTAIN TEST W-44 LEVEL 01 CH 72 ○, 73 ×, 74 +, 75 ✳

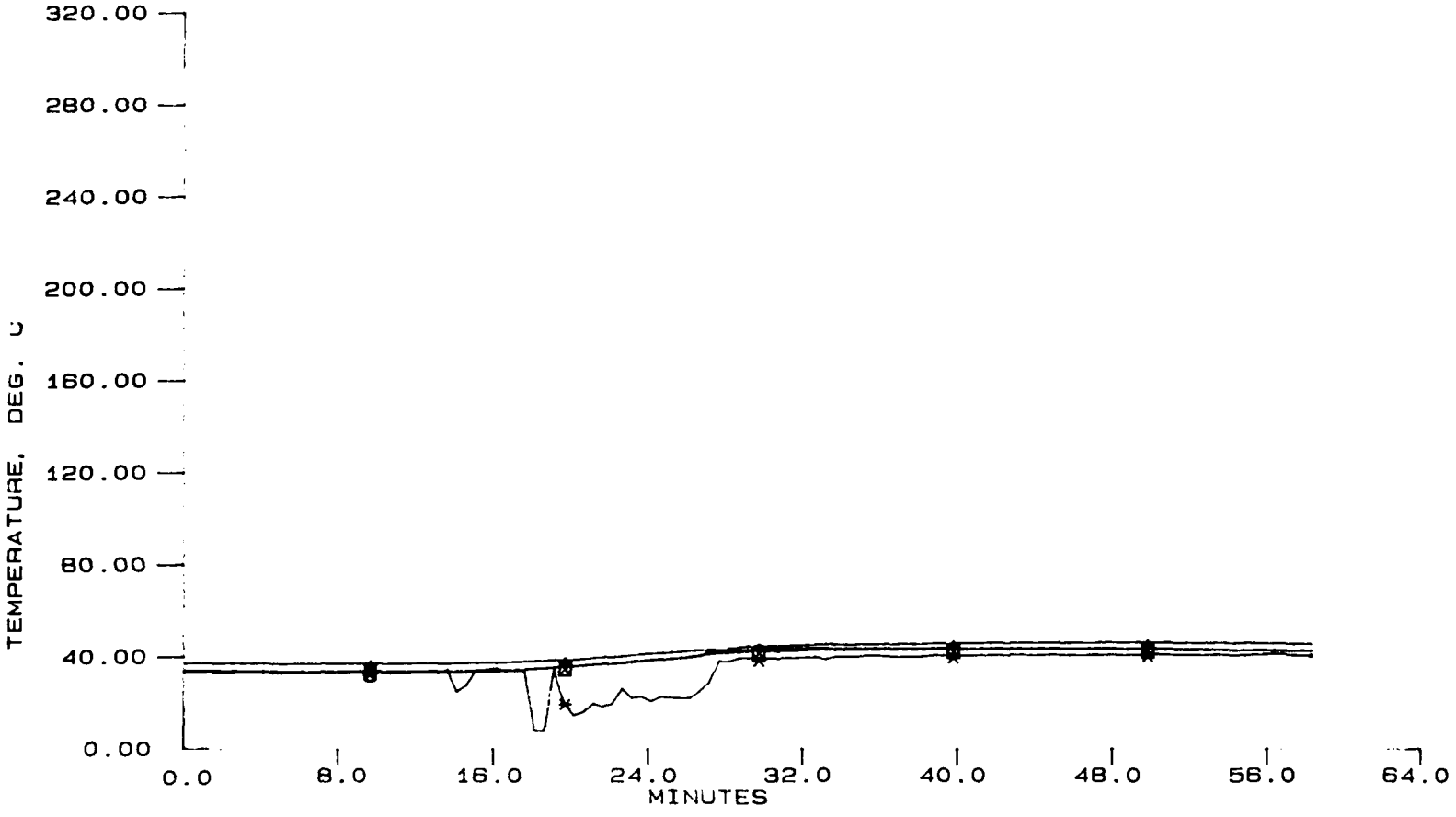


Fig. B-160 SMOKE CURTAIN TEST W-44 LEVEL 01 CH 64 O, 65 X, 66 +, 67 ✳

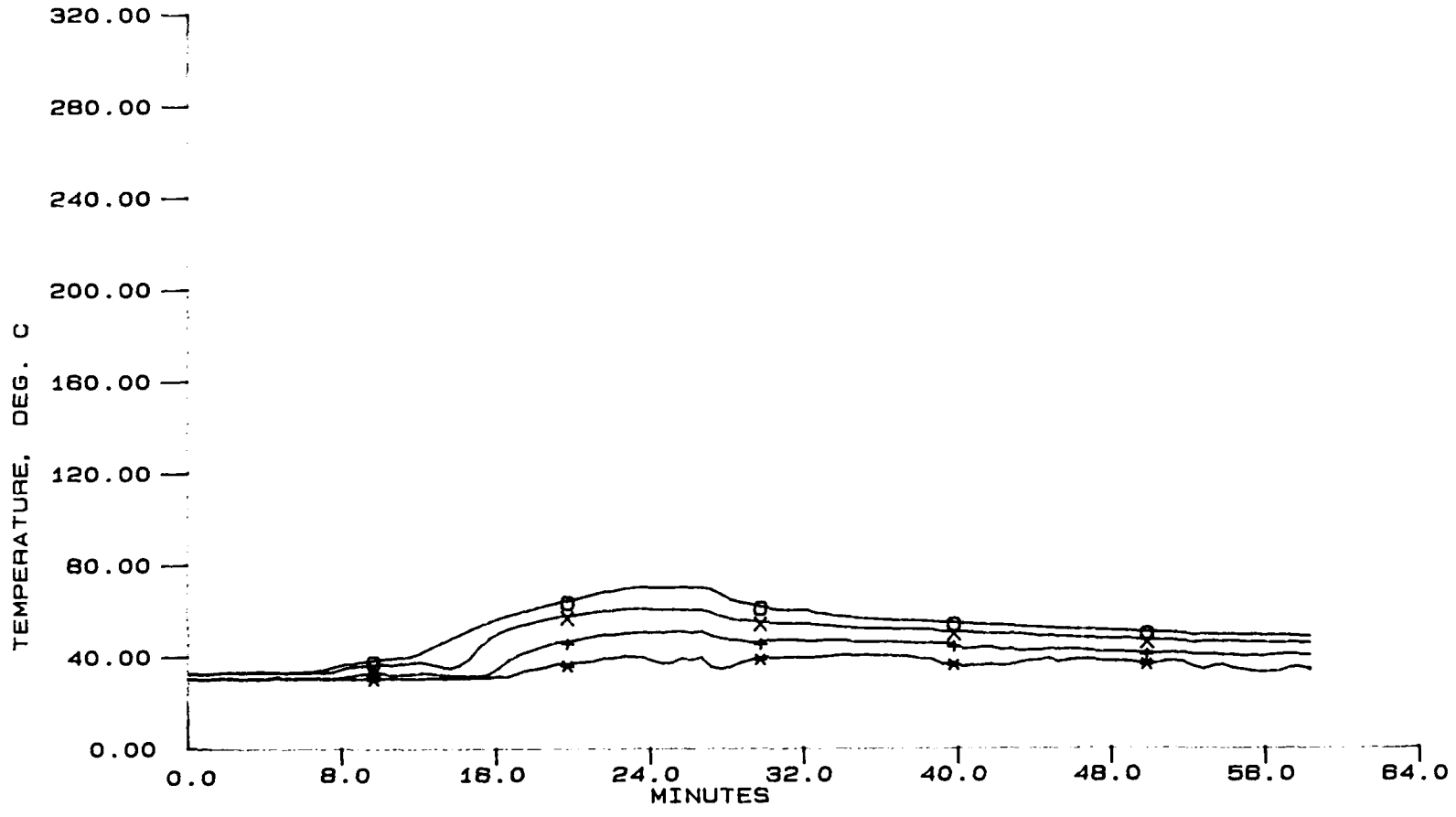


Fig. B-161 SMOKE CURTAIN TEST W-44 LEVEL 01 CH 60 ○, 61 ×, 62 +, 63 ✳

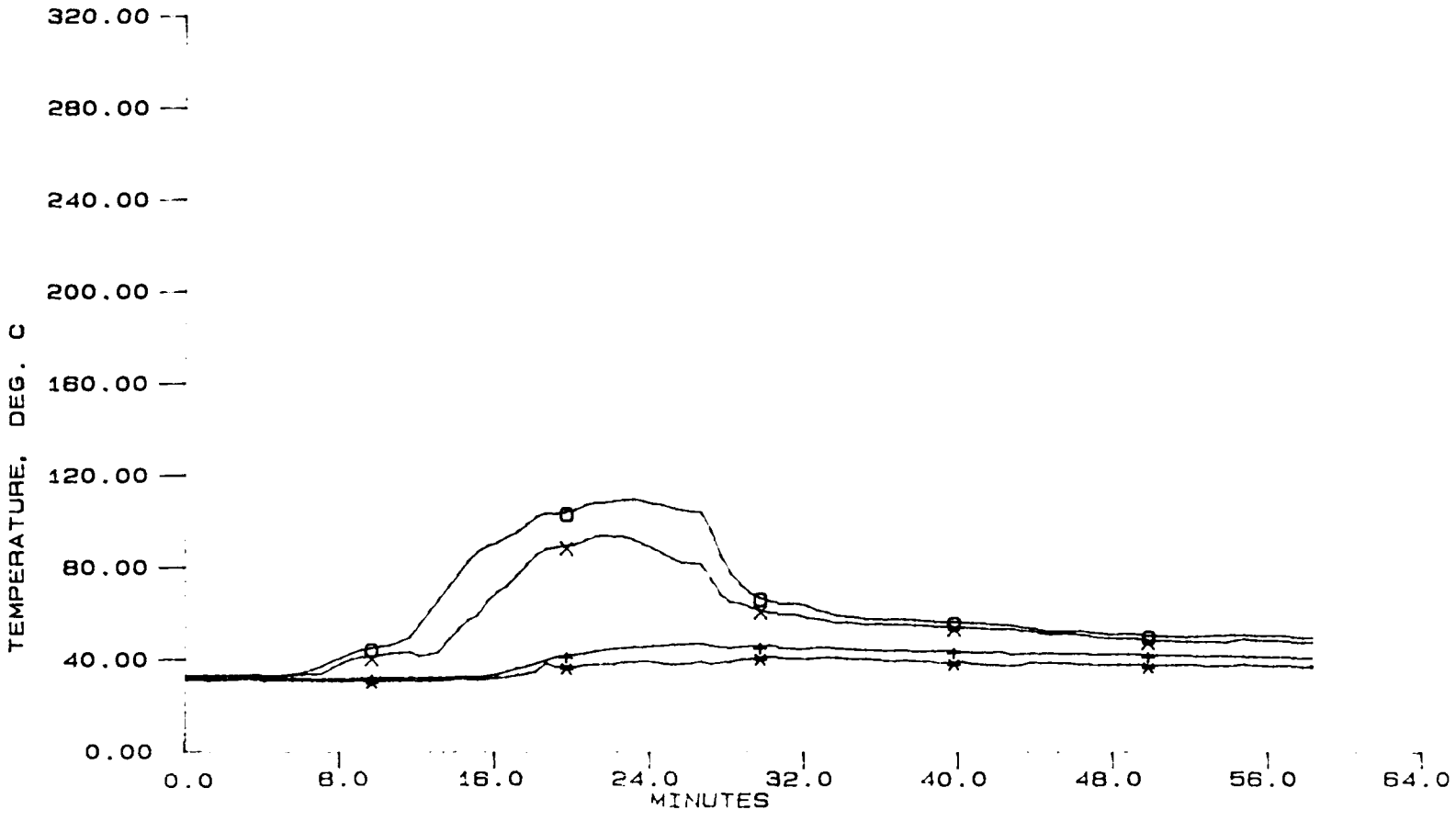


Fig. B-162 SMOKE CURTAIN TEST W-44 LEVEL 01 CH 68 ○, 69 ×, 70 +, 71 ✳

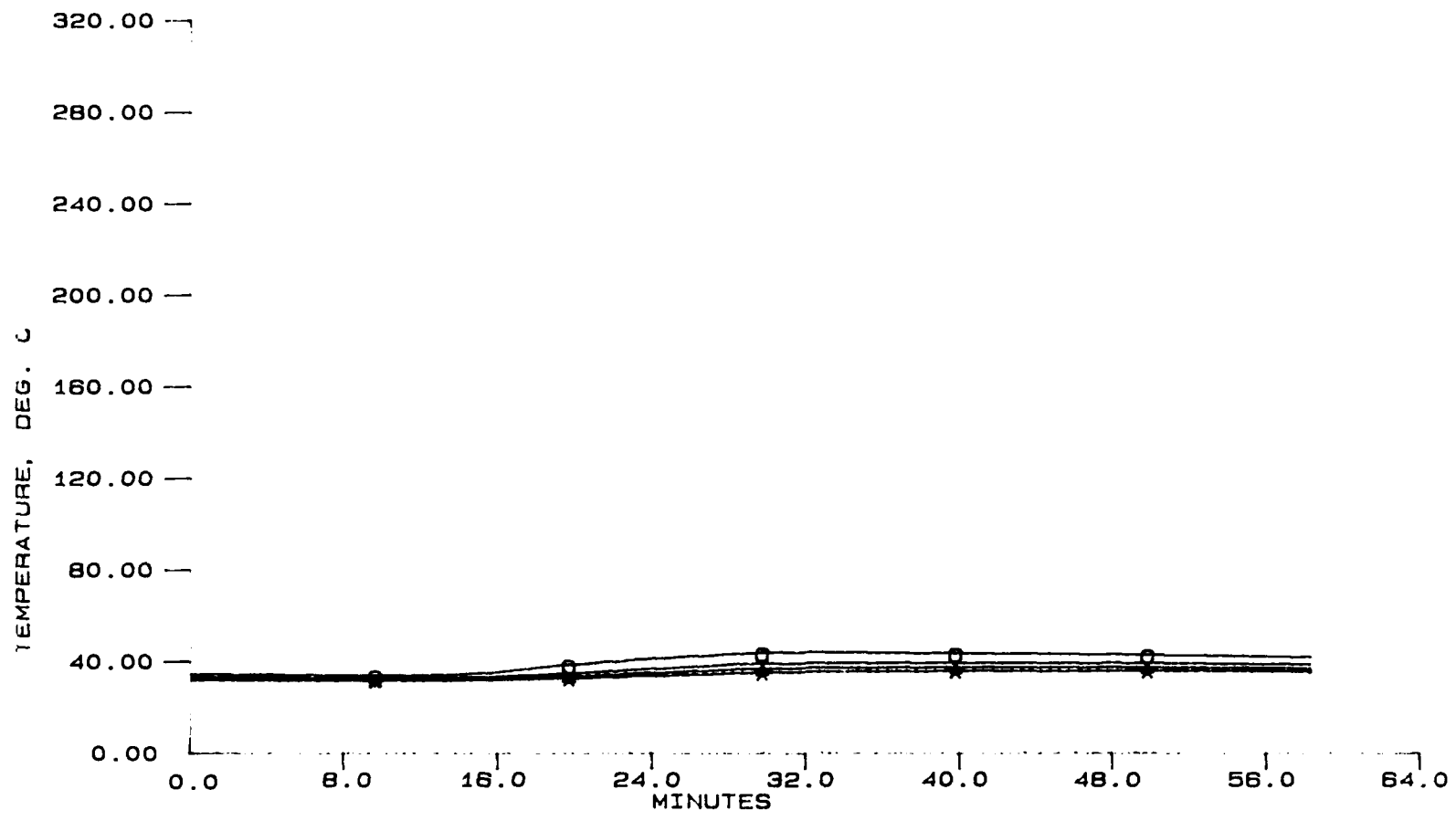


Fig. B-163 SMOKE CURTAIN TEST W-44 LEVEL 01 CH 112 ○, 113 X, 114 +, 115 ✳

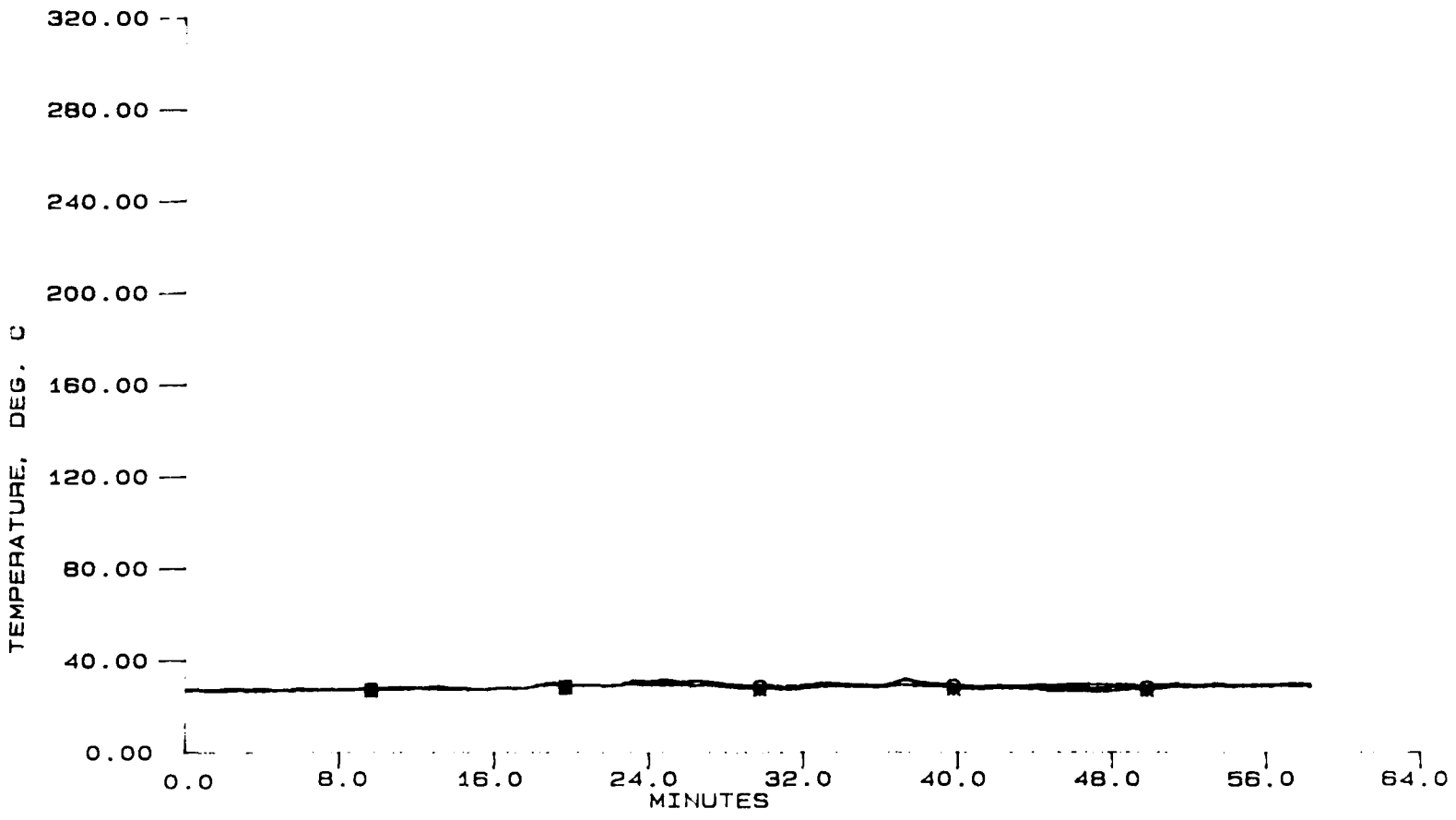


Fig. B-164 SMOKE CURTAIN TET W-44 LEVEL 01 CH 76 ○, 77 X, 78 +, 79 ✳

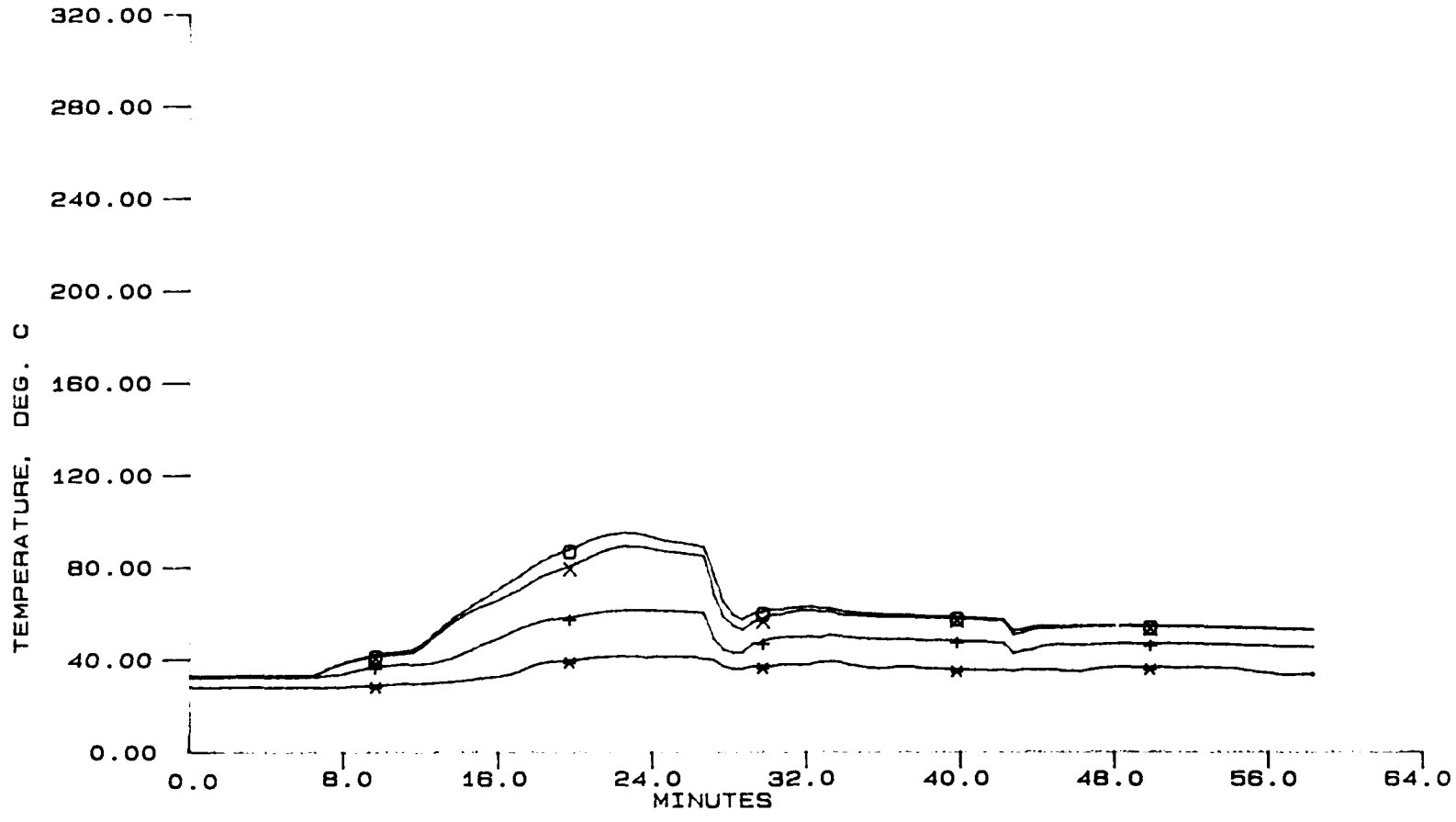


Fig. B-165 SMOKE CURTAIN TEST W-44 LEVEL 01 CH 80 O, 81 X, 82 +, 83 *

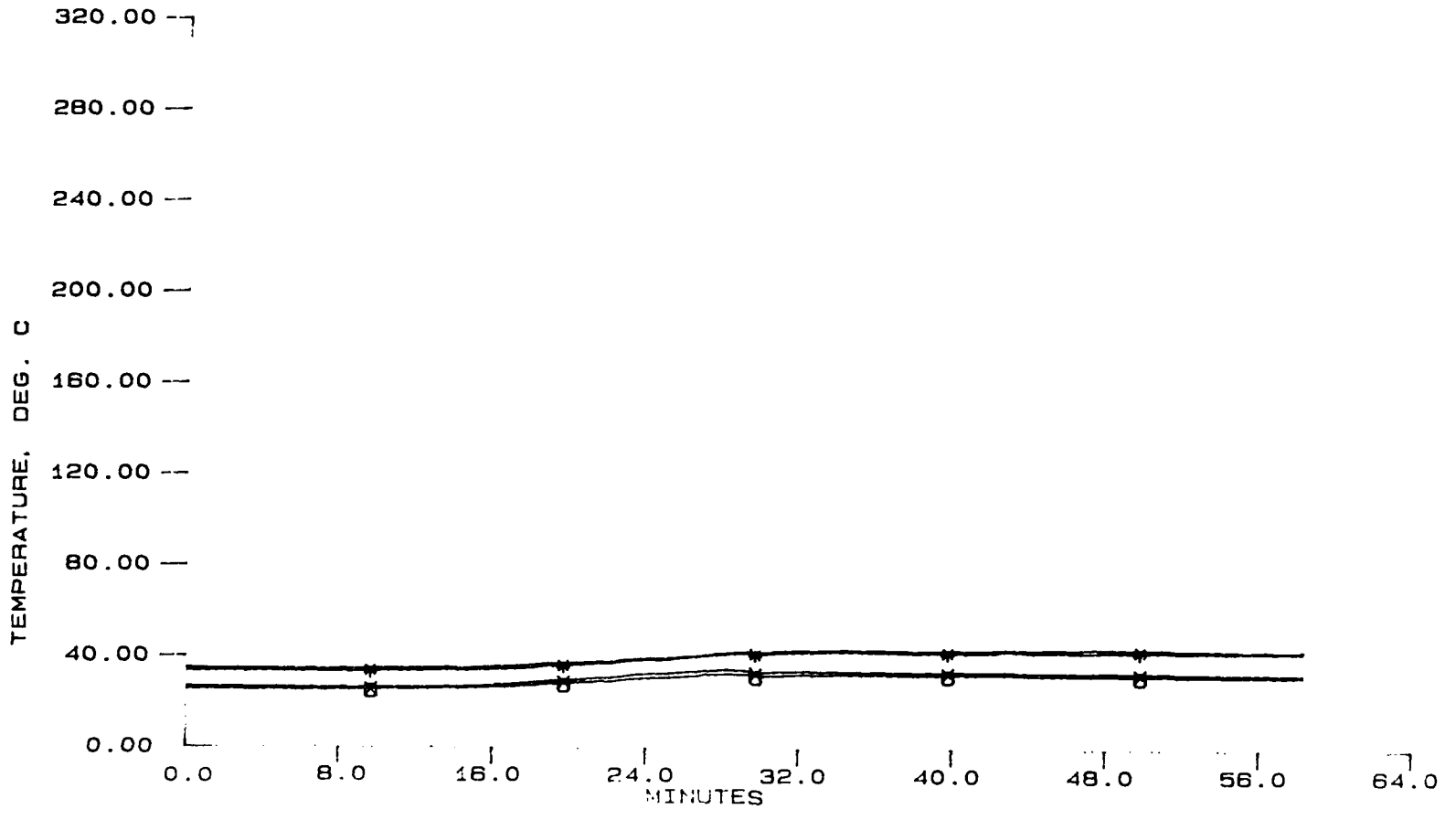


Fig. B-166 SMOKE CURTAIN TEST W-44 LEVEL 01 CH 84 O, 85 X, 86 +, 87 ✳

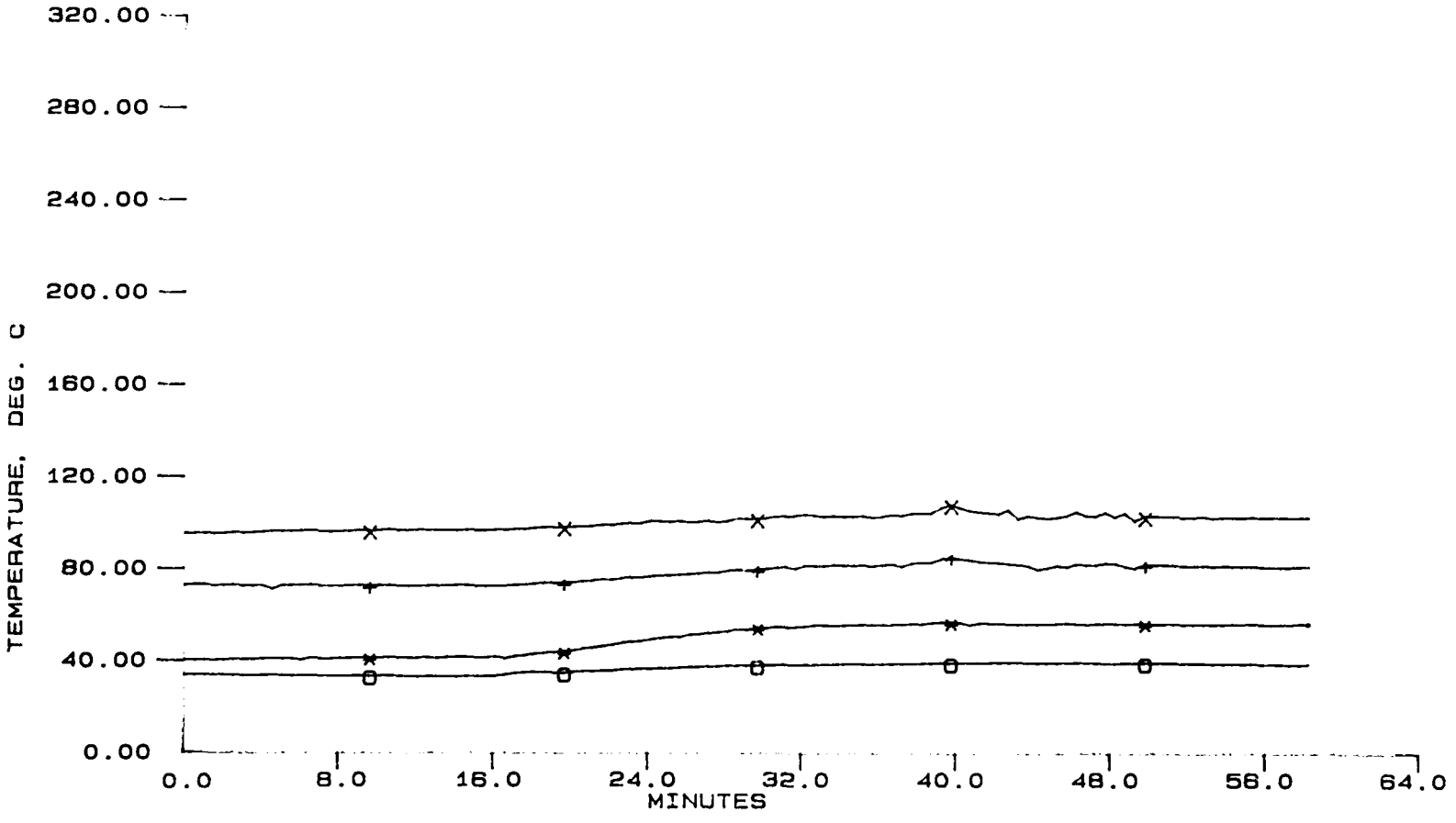


Fig. B-167 SMOKE CURTAIN TEST W-44 MAIN DECK CH 104 ○, 105 X, 106 +, 107 ✳

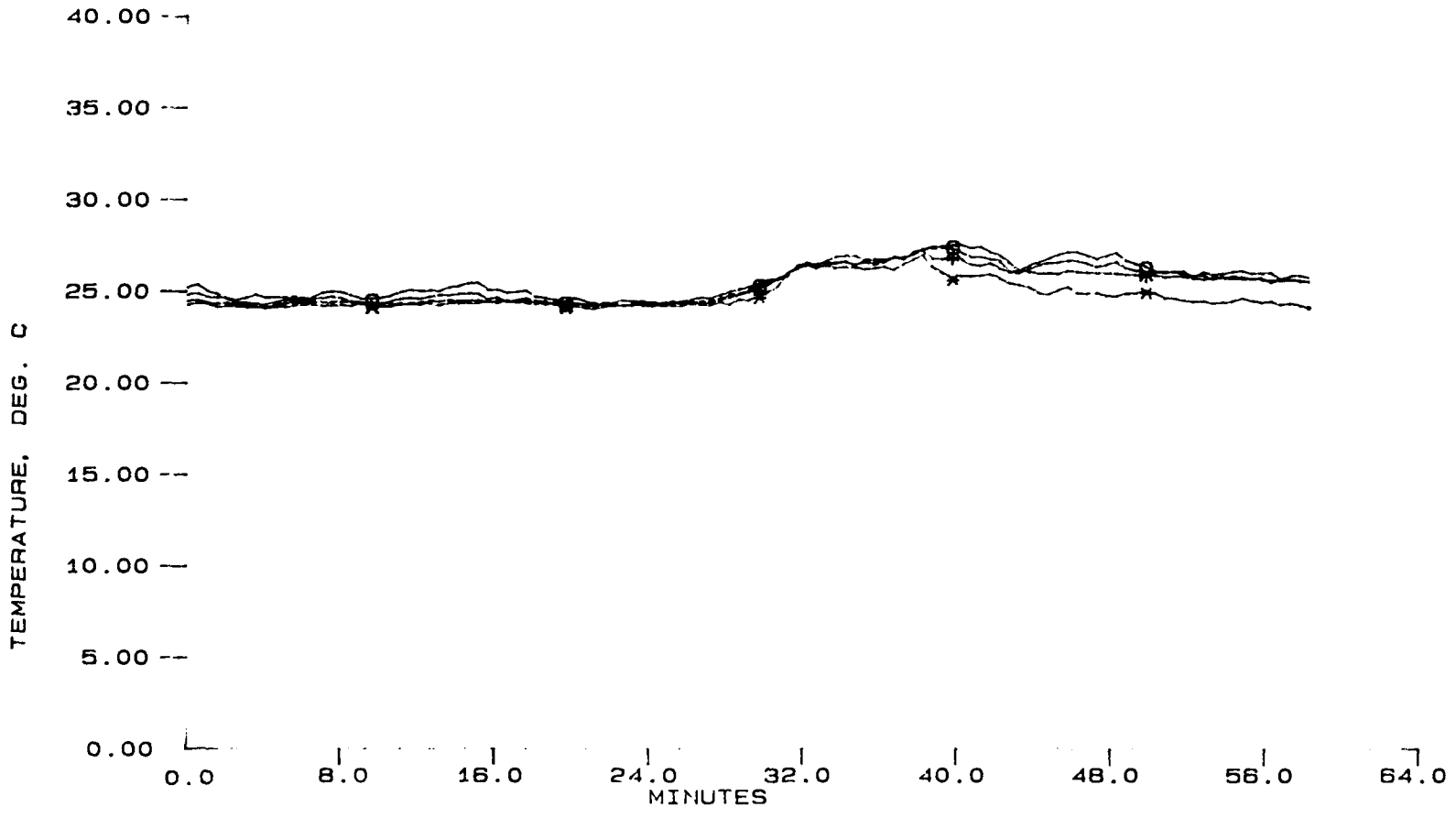


Fig. B-168 SMOKE CURTAIN TEST W-44 MAIN DECK CH 100 ○, 101 ×, 102 +, 103 ✳

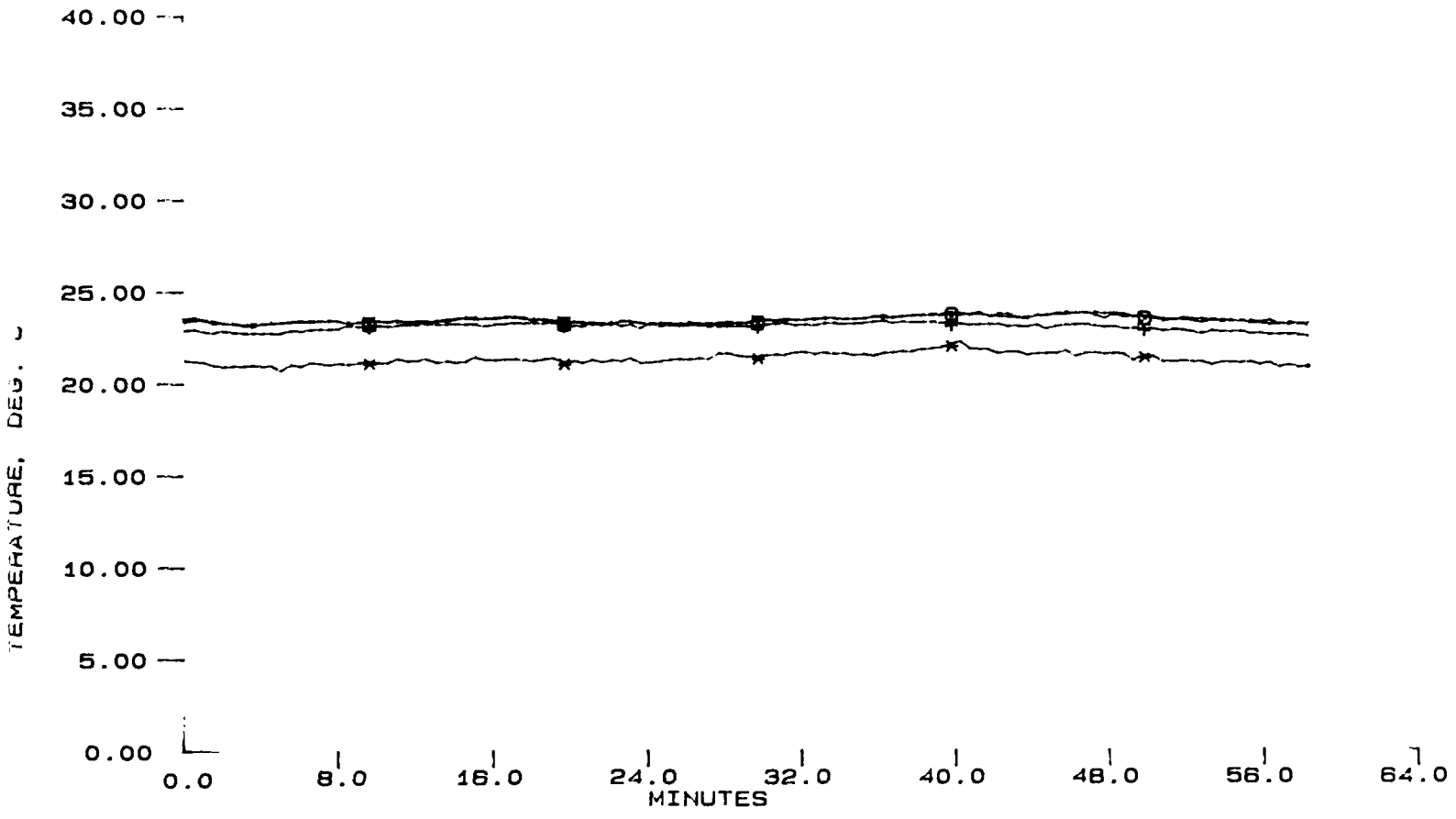


Fig. B-169 SMOKE CURTAIN TEST W-44 MAIN DECK CH 108 ○, 109 ×, 110 +, 111 ✳

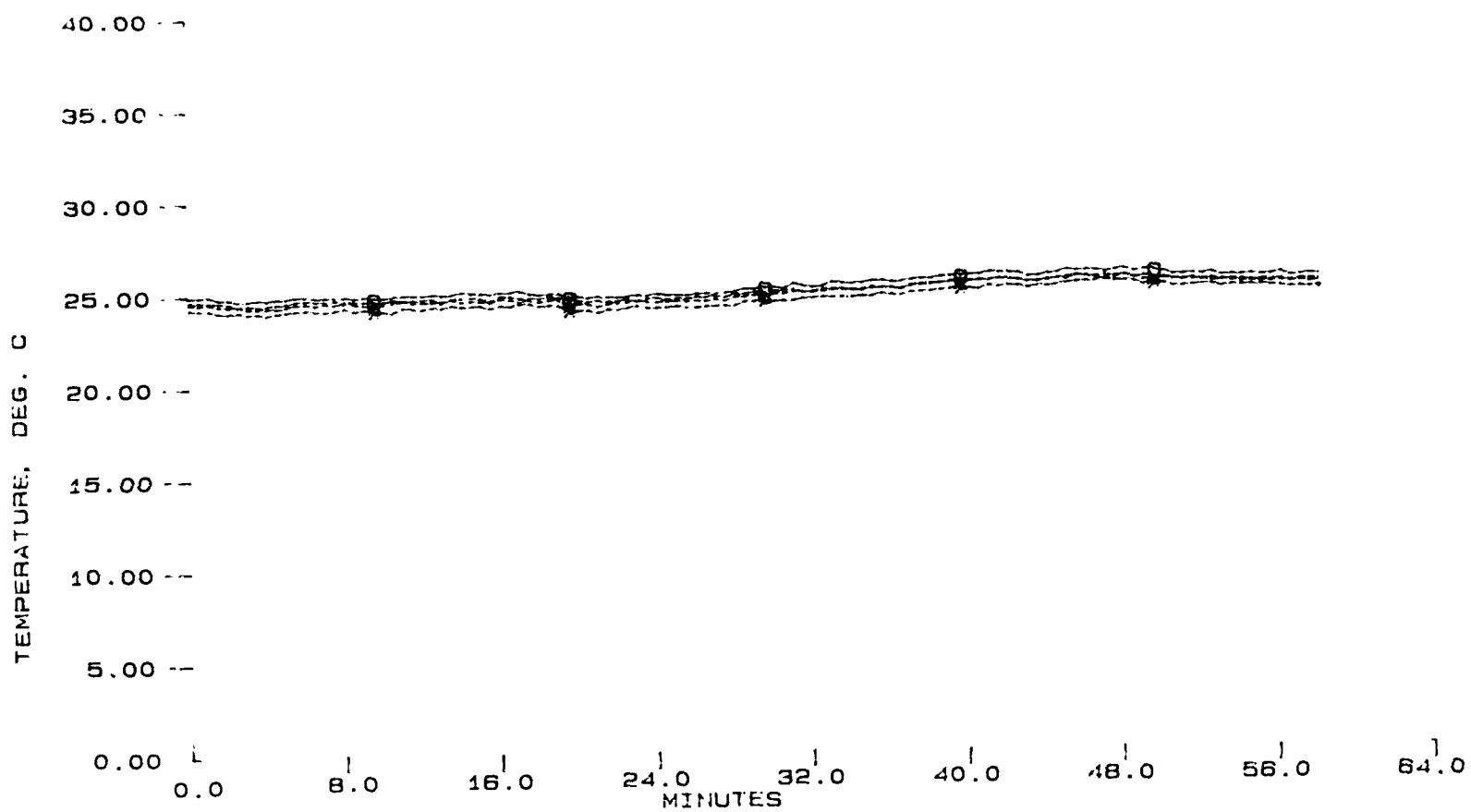
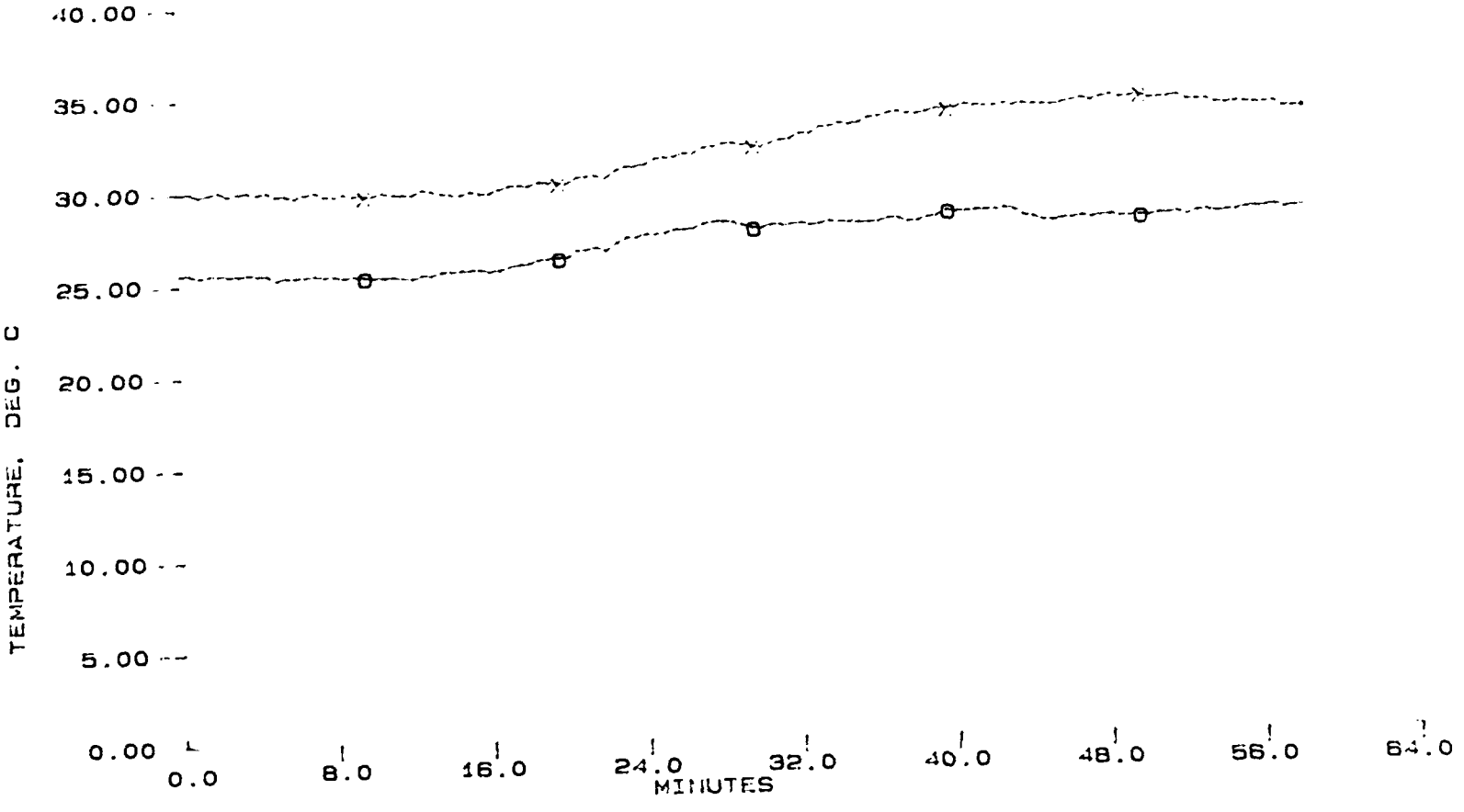


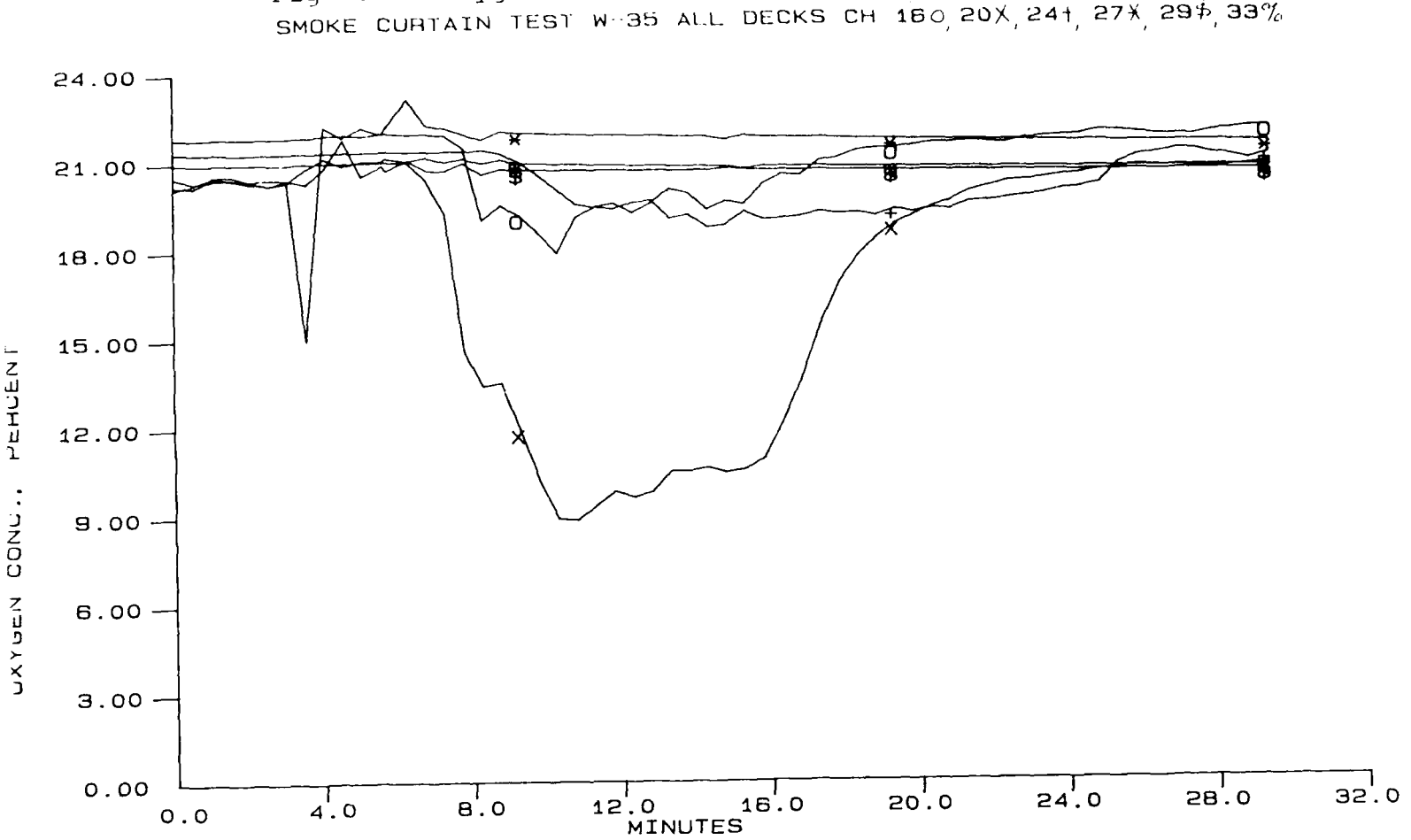
Fig. B-170 SMOKE CURTAIN TEST W-44 MAIN DECK CH 94 O, 98 X



APPENDIX C

Gas Composition

Fig C-1 Oxygen Concentrations during Test W-35



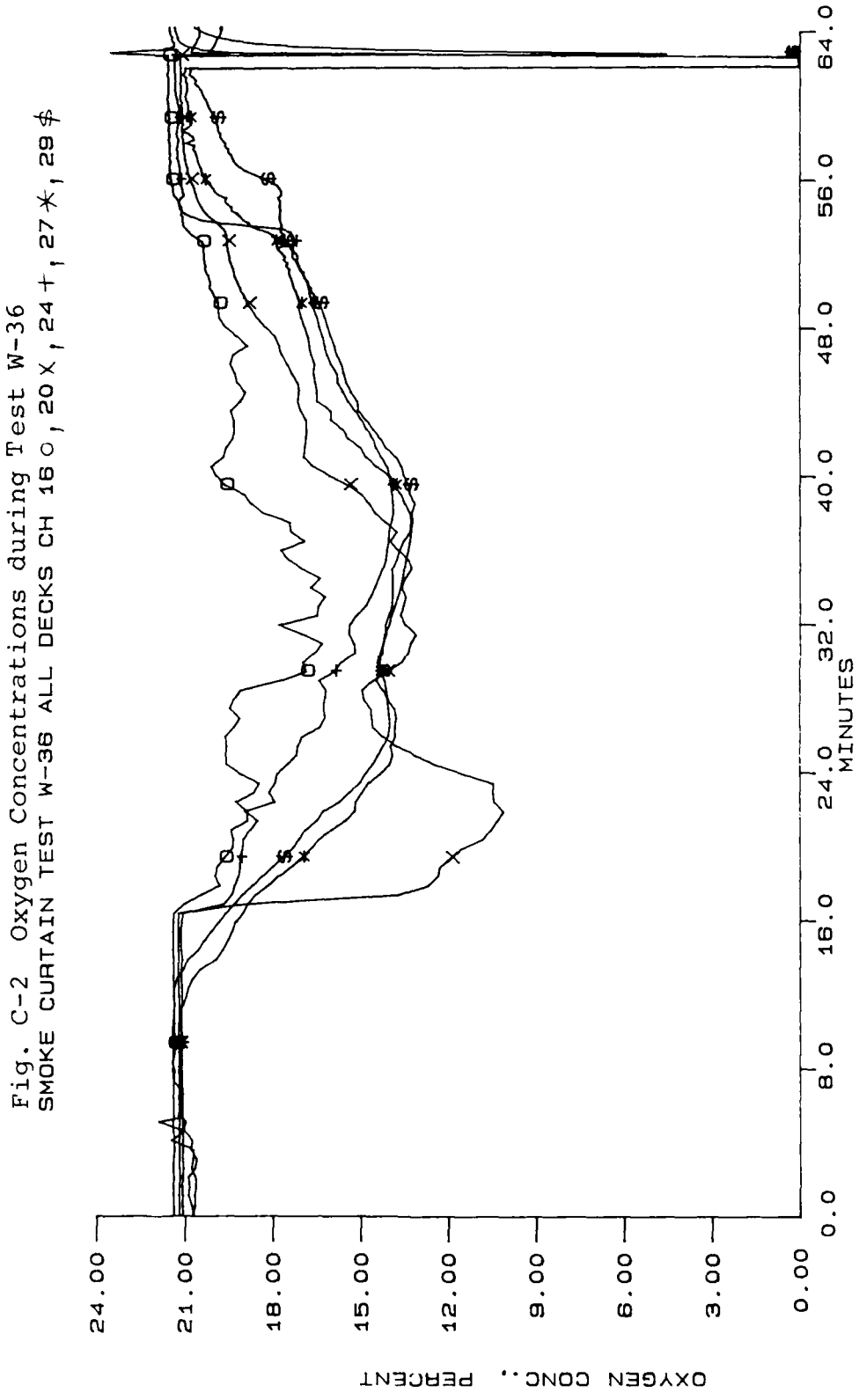
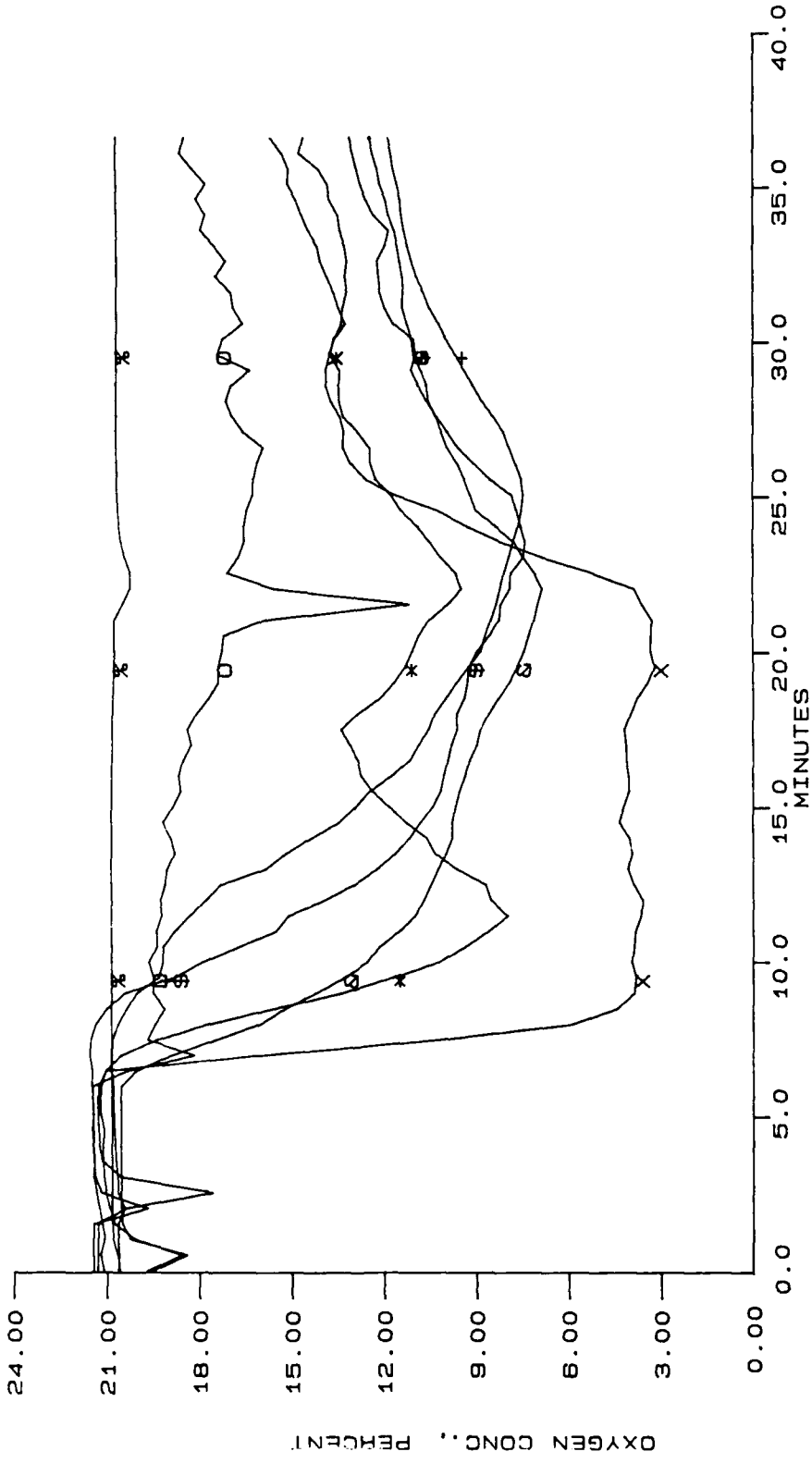


Fig. C-2 Oxygen Concentrations during Test W-36
SMOKE CURTAIN TEST W-36 ALL DECKS CH 16 ○, 20 X, 24 +, 27 ✳, 29 $
OXYGEN CONC., PERCENT
24.00
21.00
18.00
15.00
12.00
9.00
6.00
3.00
0.00
0.0
8.0
16.0
24.0
32.0
40.0
48.0
56.0
64.0
MINUTES

Fig. C-3 Oxygen Concentrations during Test W-37
SMOKE CURTAIN TEST W-37 ALL DECKS CH 16◇, 20X, 24+, 27*, 29$, 31%, 33&



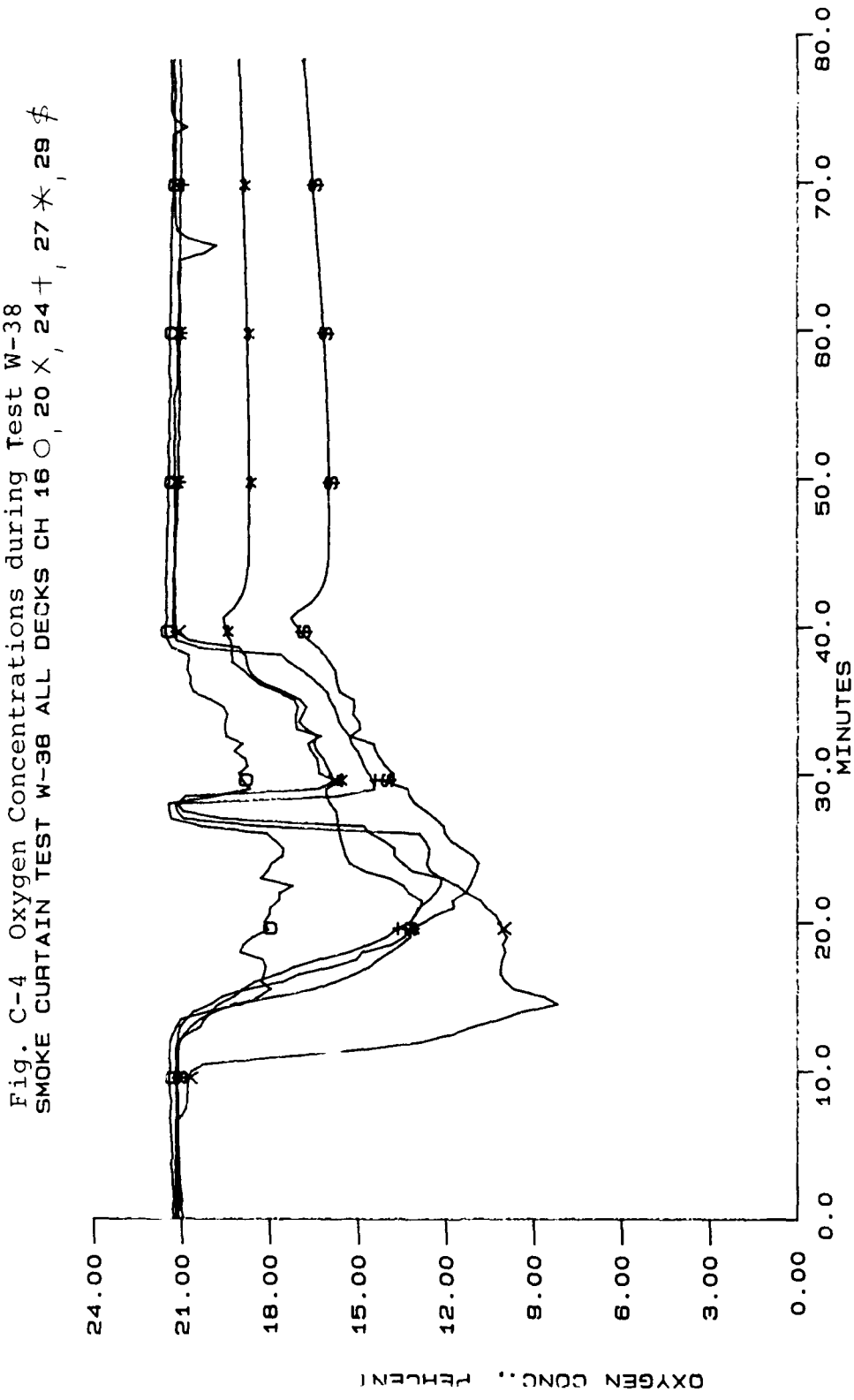


Fig. C-4 Oxygen Concentrations during Test W-38
SMOKE CURTAIN TEST W-38 ALL DECKS CH 16 ○, 20 ×, 24 +, 27 ✳, 29 ∮
OXYGEN CONC., PERCENT
24.00
21.00
18.00
15.00
12.00
9.00
6.00
3.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
MINUTES

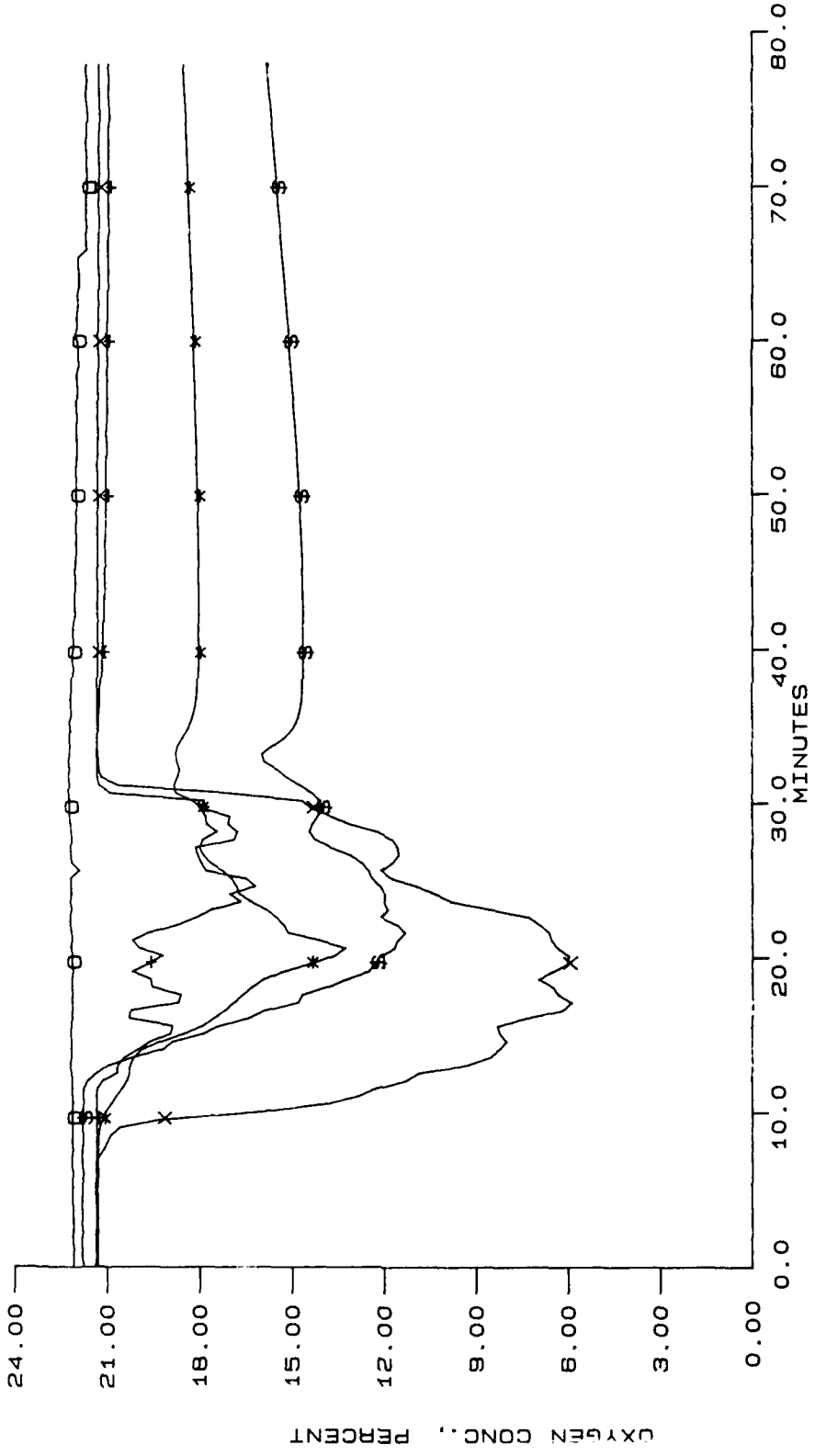


Fig. C-5 Oxygen Concentrations during Test W-39
SMOKE CURTAIN TEST W-39 ALL DECKS CH 16 O, 20 X, 24 +, 27 *, 29 $
OXYGEN CONC., PERCENT
24.00
21.00
18.00
15.00
12.00
9.00
6.00
3.00
0.00
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
MINUTES

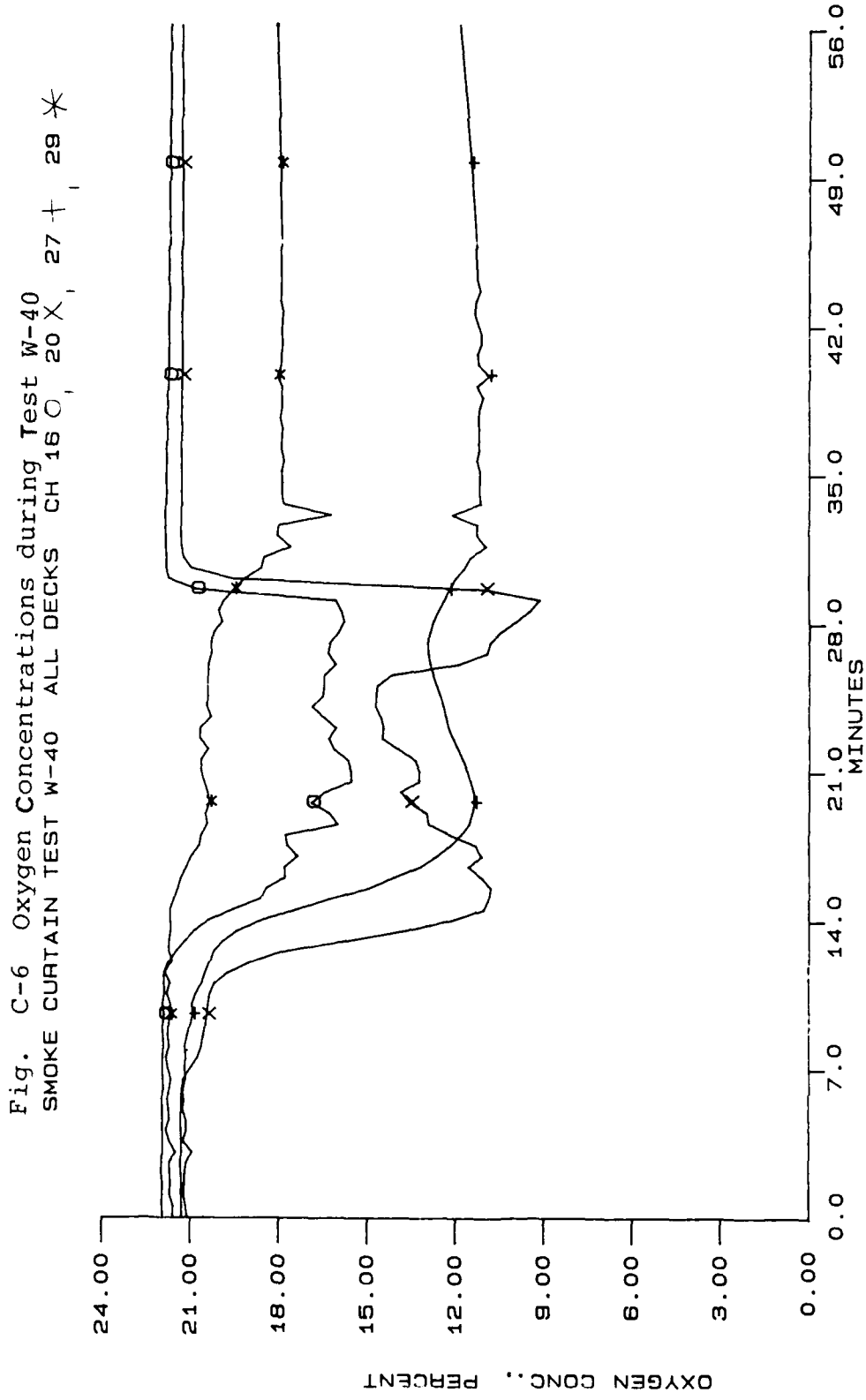
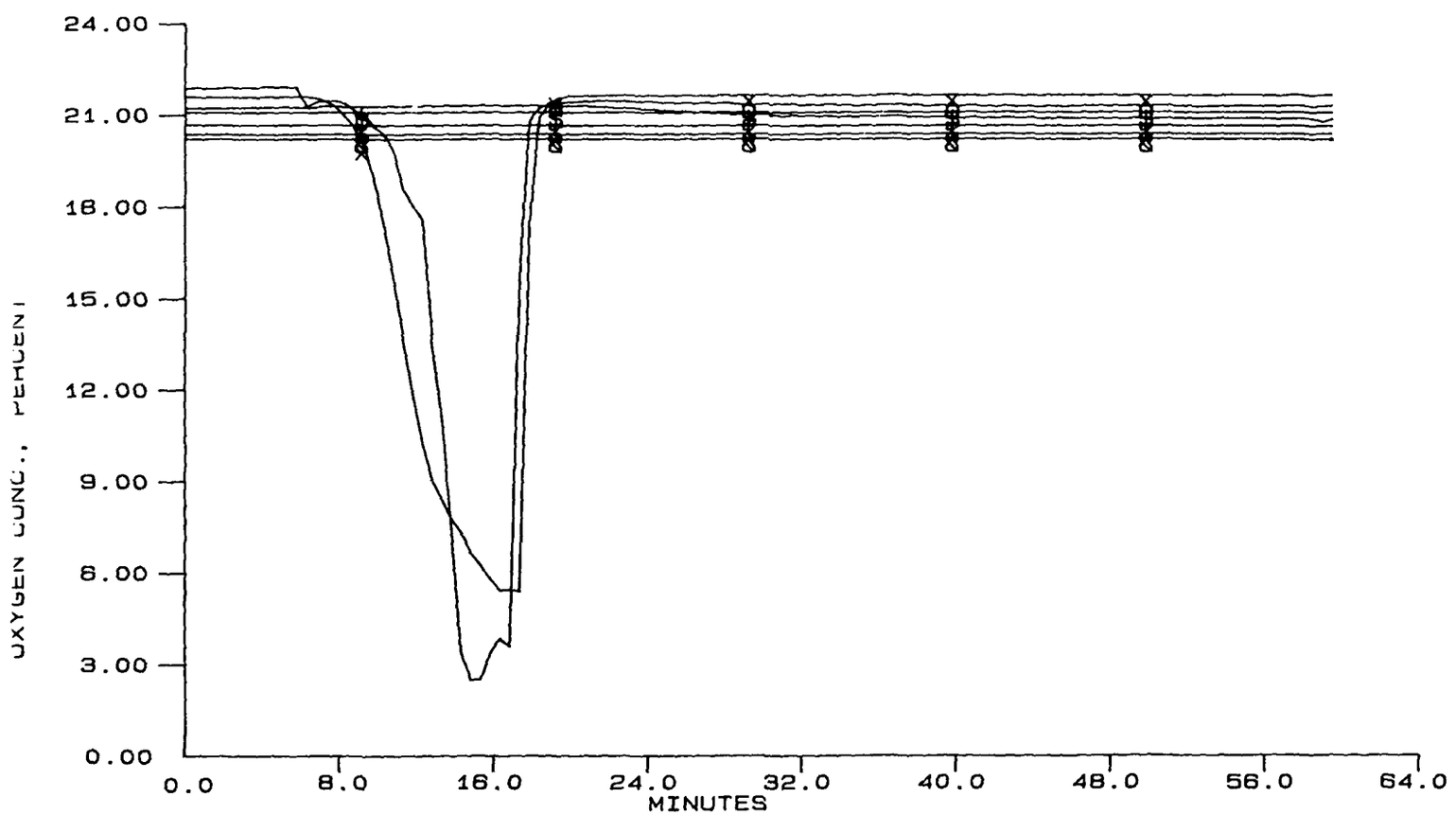


Fig. C-6 Oxygen Concentrations during Test W-40
SMOKE CURTAIN TEST W-40 ALL DECKS CH 16 O, 20 X, 27 +, 29 *
OXYGEN CONC., PERCENT
24.00
21.00
18.00
15.00
12.00
9.00
6.00
3.00
0.00
0.0
7.0
14.0
21.0
28.0
35.0
42.0
49.0
56.0
MINUTES

Fig. C-7 Oxygen Concentrations during Test W-41



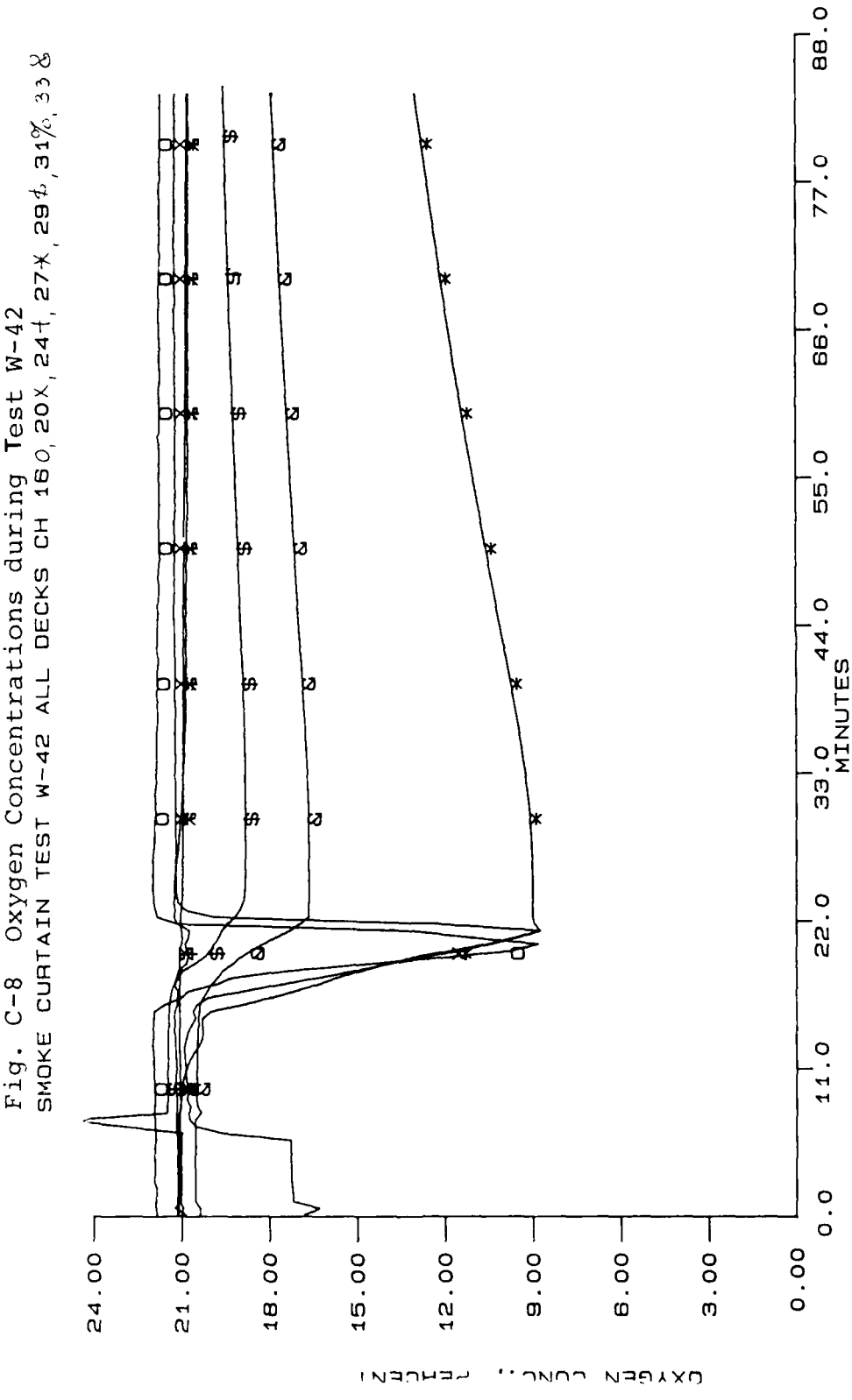


Fig. C-8 Oxygen Concentrations during Test W-42
SMOKE CURTAIN TEST W-42 ALL DECKS CH 16, 20, 24, 27, 29, 31, 33 &

Fig. C-9 Oxygen Concentrations during Test W-43
SMOKE CURTAIN TEST W-43 ALL DECKS CH 16, 22*, 24, 27*, 29$, 31%, 33&

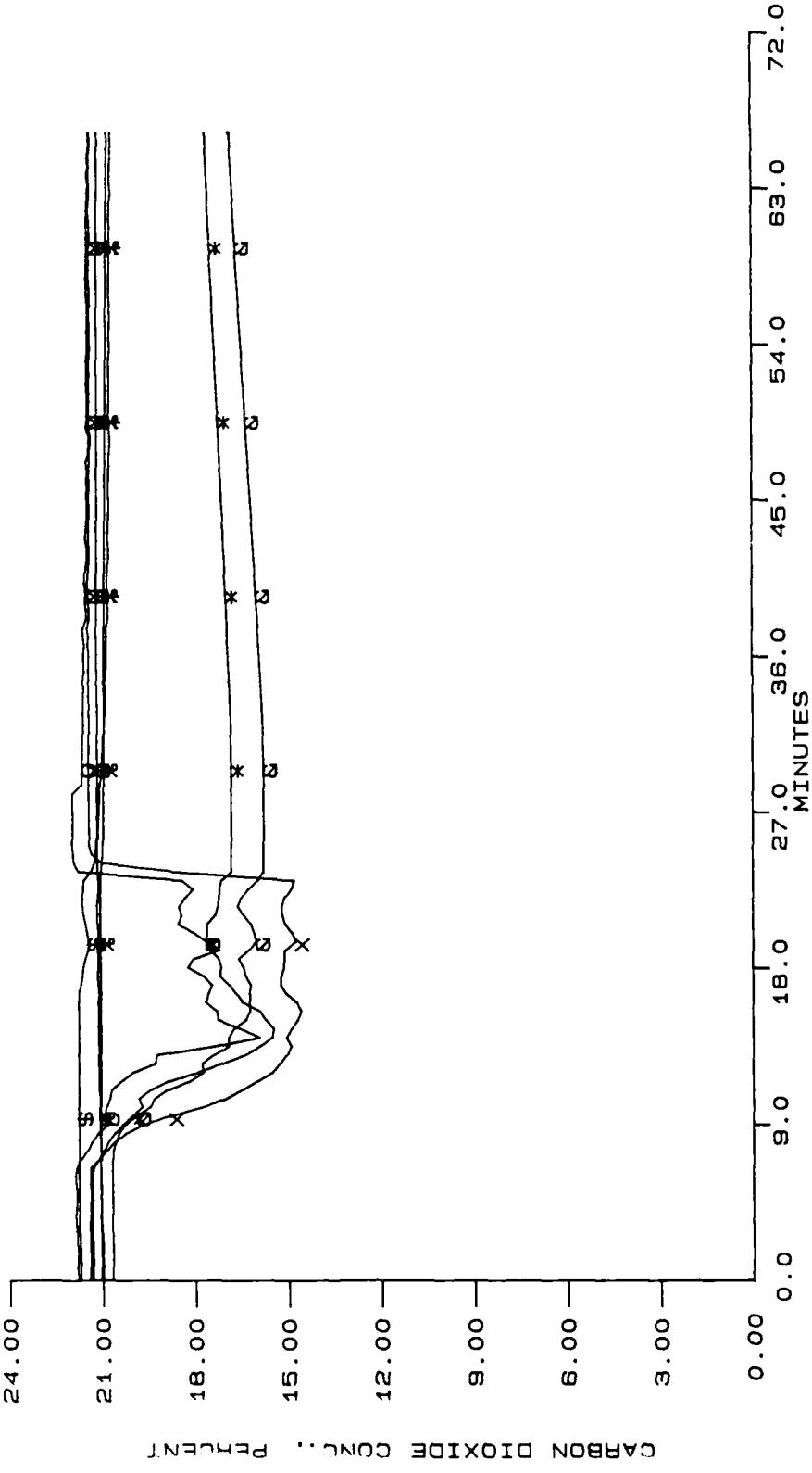


Fig. C-10 Oxygen Concentrations during Test W-44
SMOKE CURTAIN TEST W-44 ALL DECKS CH 16, 20, 24, 27, 29, 31, 33

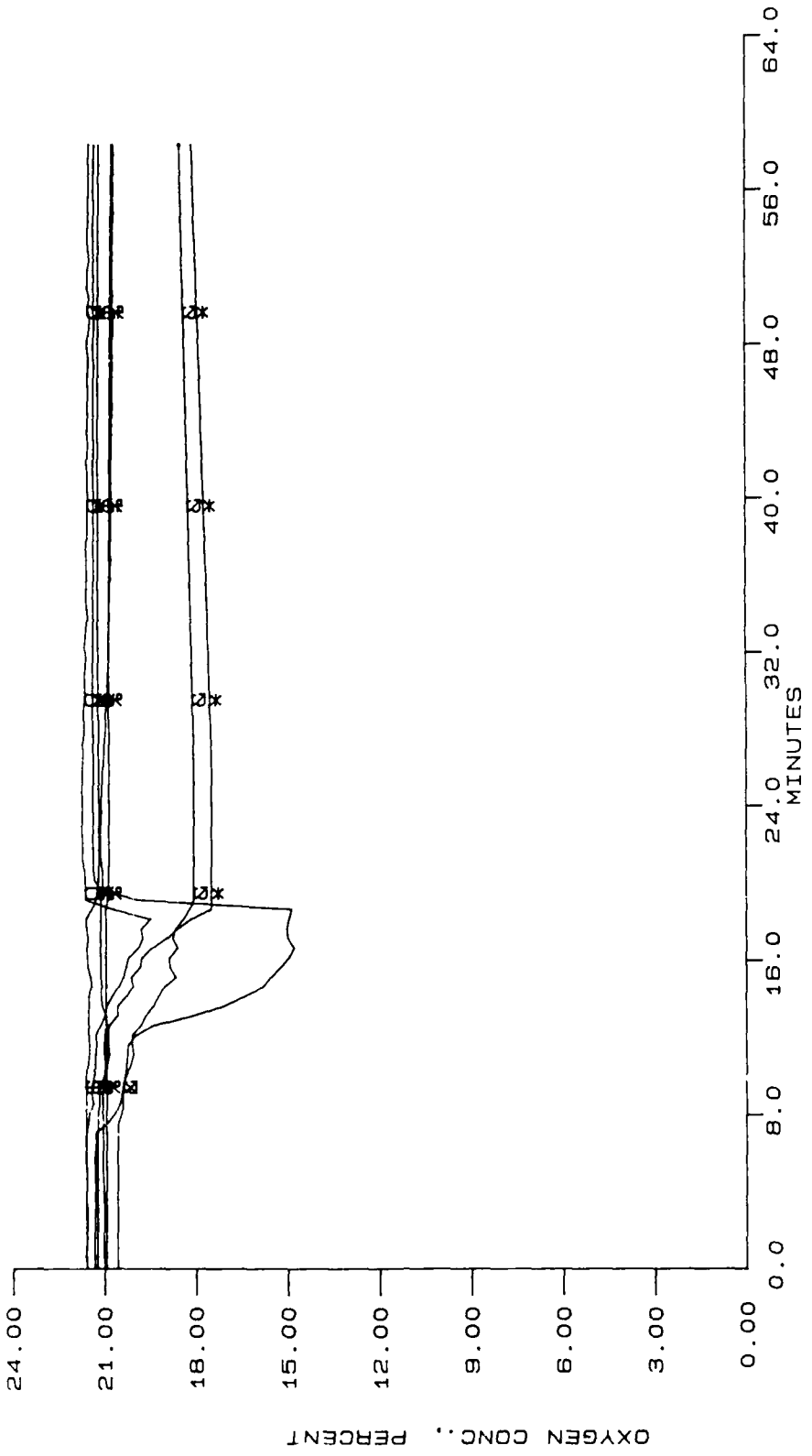


Fig. C-11 Carbon Dioxide Concentrations during Test W-35
SMOKE CURTAIN TEST W-35 ALL DECKS CH 18◇, 22X, 26+, 28*, 30$, 32%

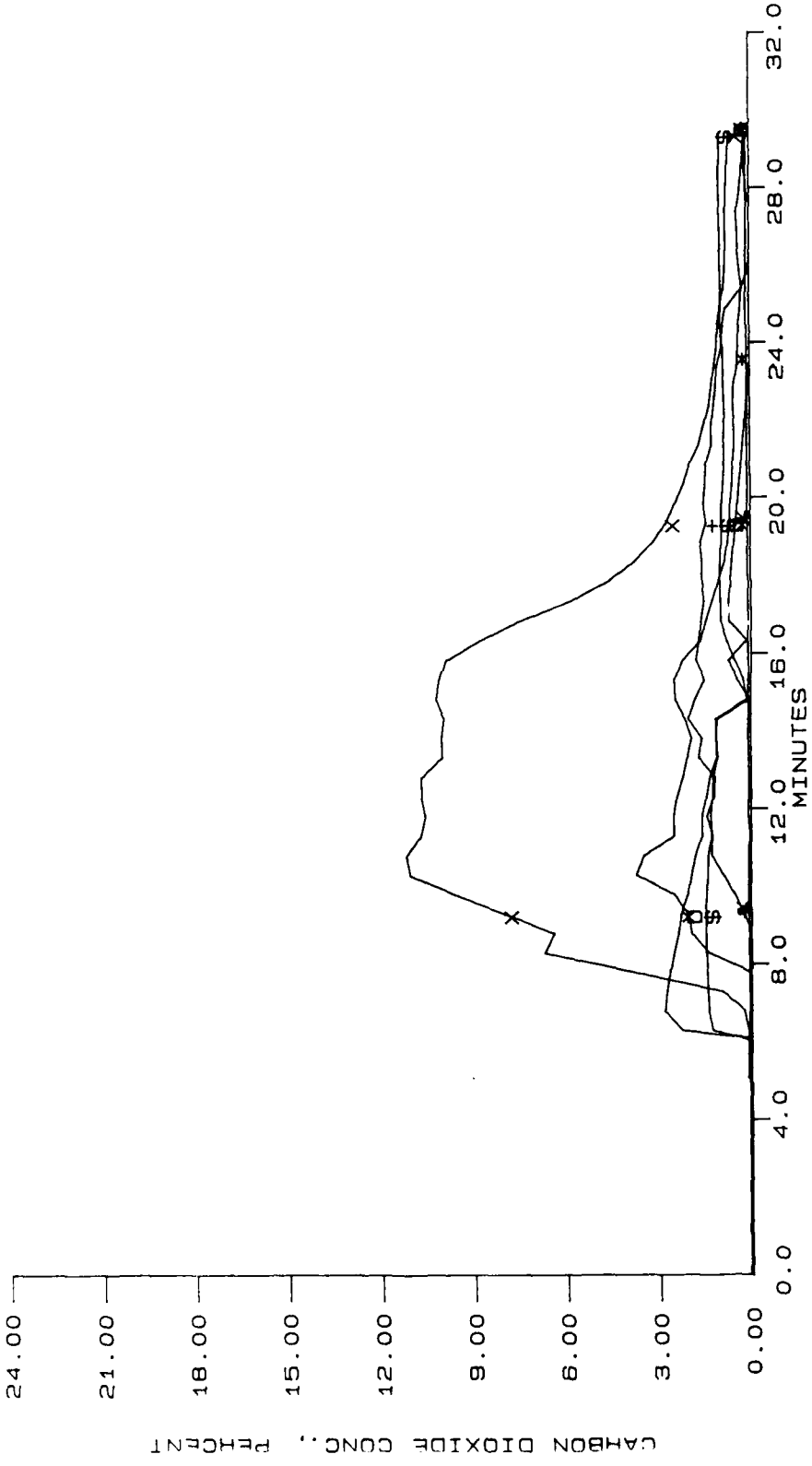


Fig. C-12 Carbon Dioxide Concentrations during Test W-36

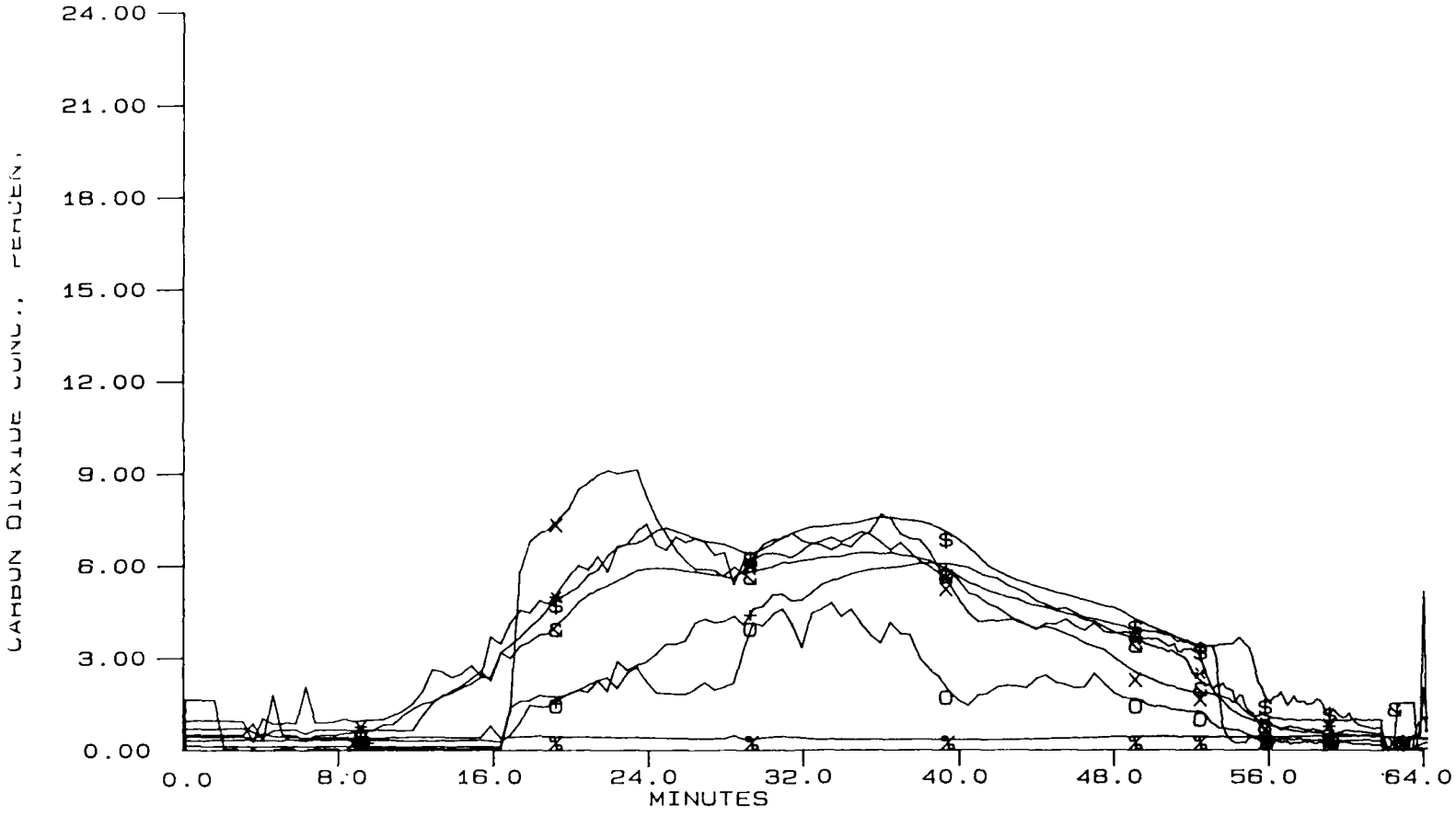


Fig. C-13 Carbon Dioxide Concentrations during Test W-37

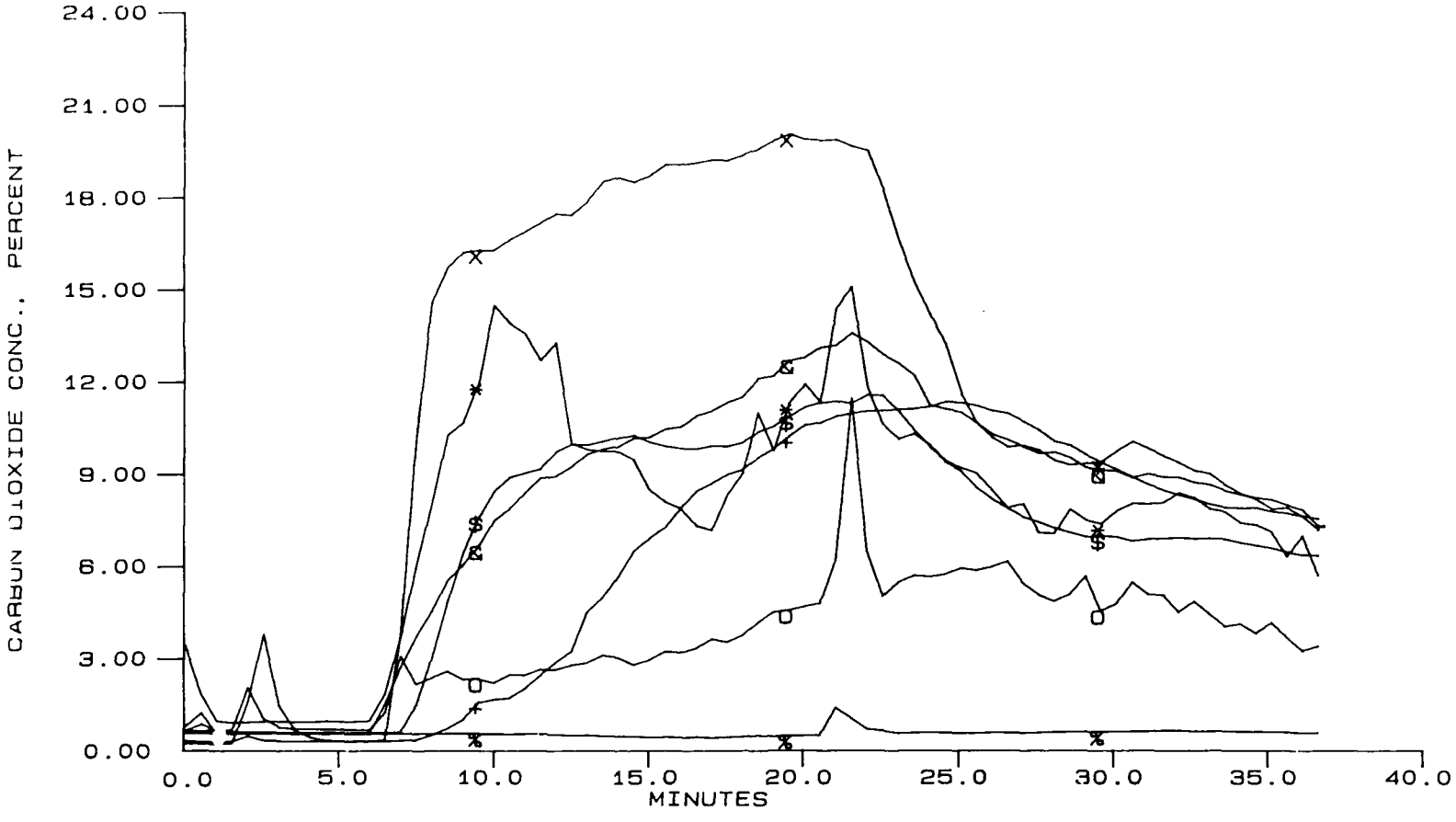


Fig. C-14 Carbon Dioxide Concentrations during Test W-38

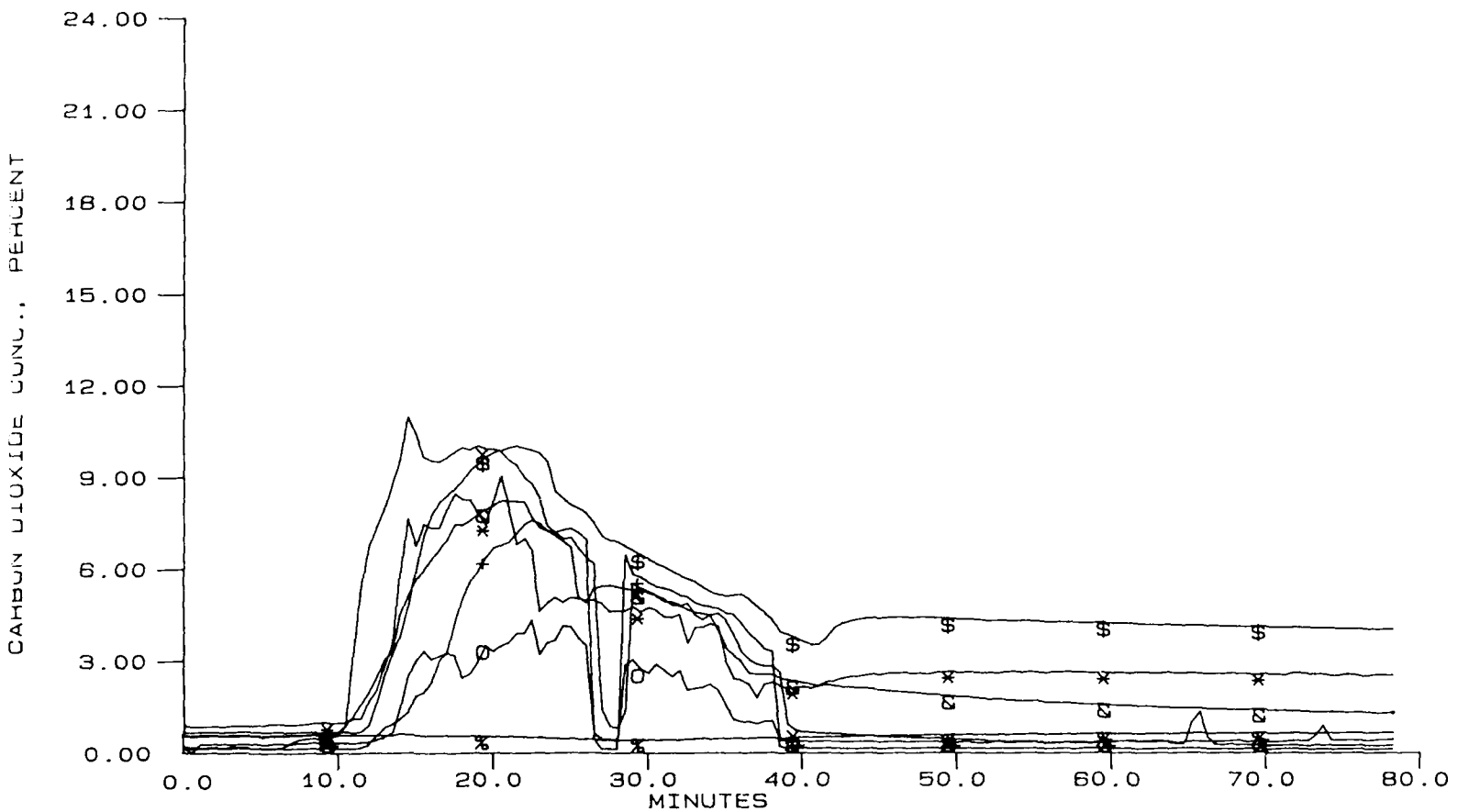


Fig. C-15 Carbon Dioxide Concentrations during Test W-39

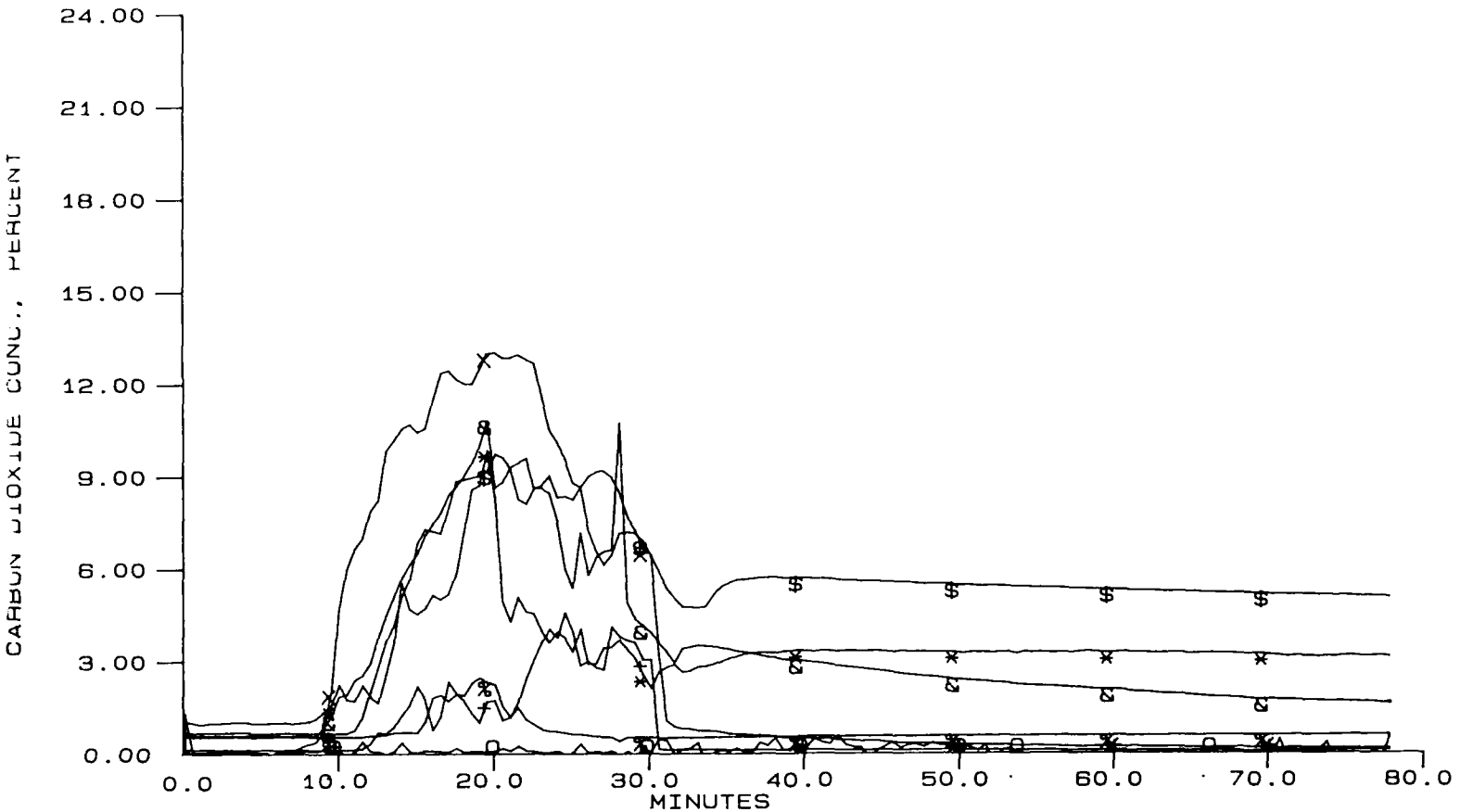


Fig. C-16 Carbon Dioxide Concentrations during Test W-40

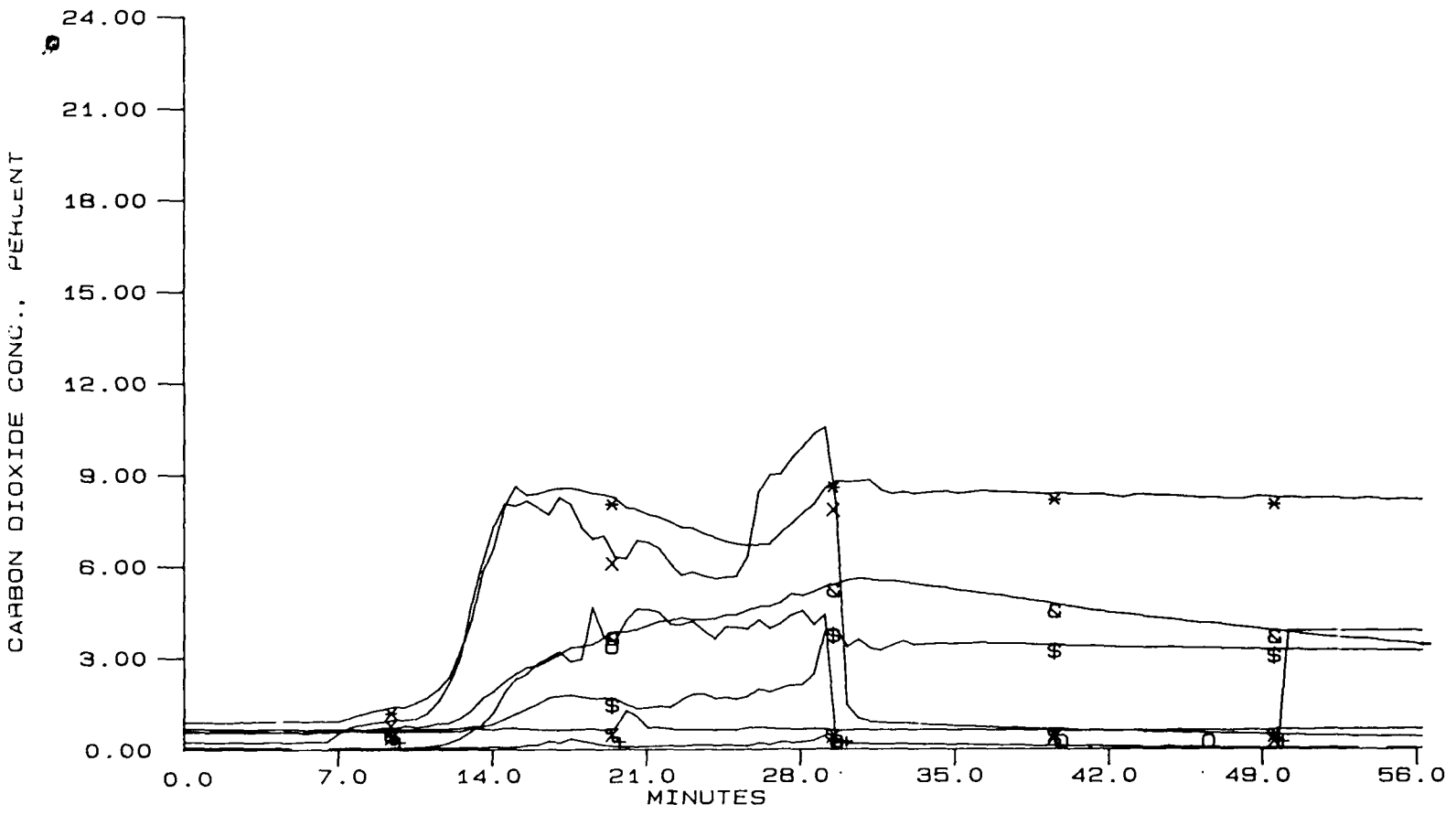


Fig. C-17 Carbon Dioxide Concentrations during Test W-41
SMOKE CURTAIN TEST W-41 ALL DECKS CH 18%, 22%, 28%, 30%, 32%, 34%

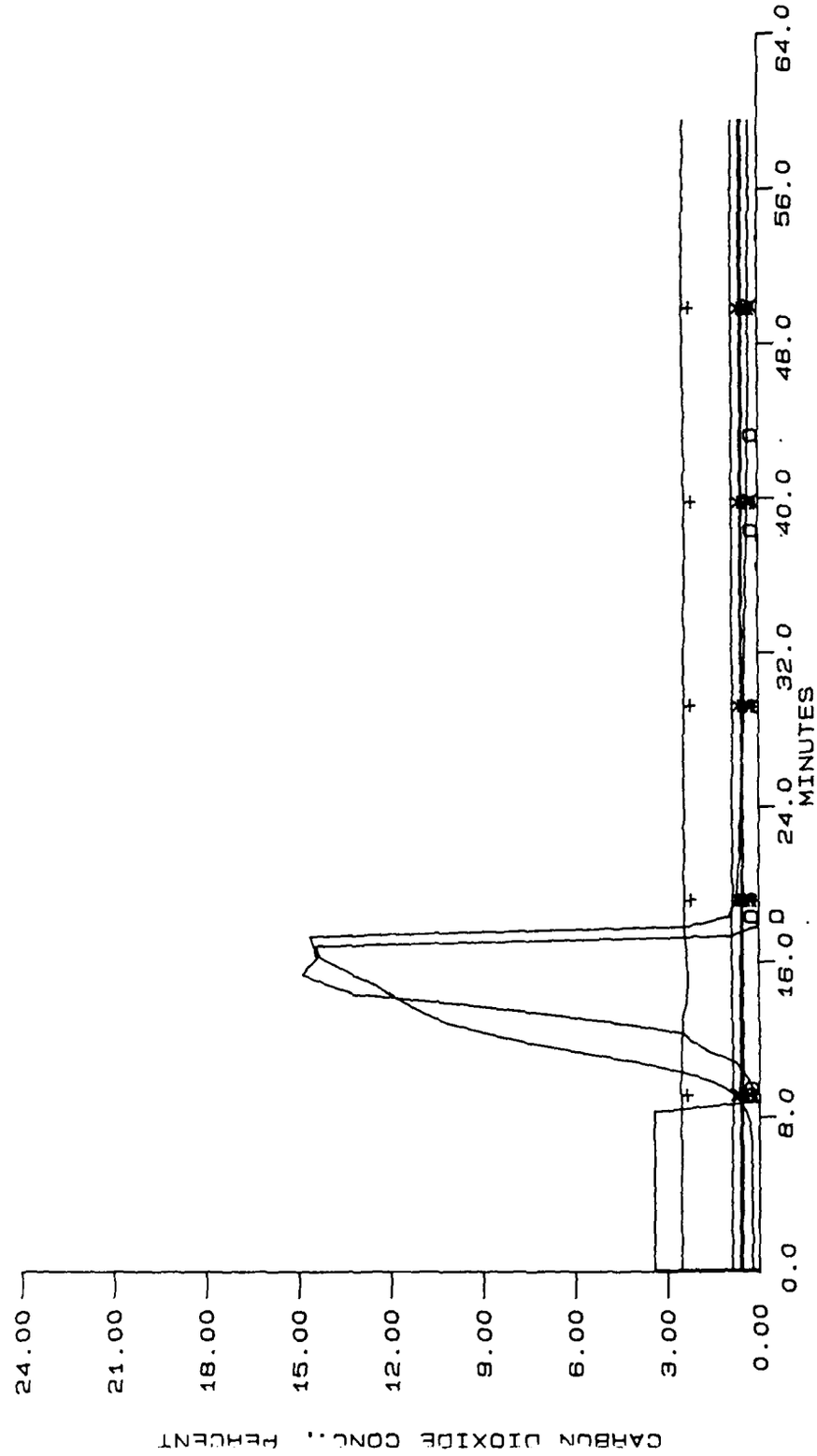


Fig. C-18 Carbon Dioxide Concentrations during Test W-42

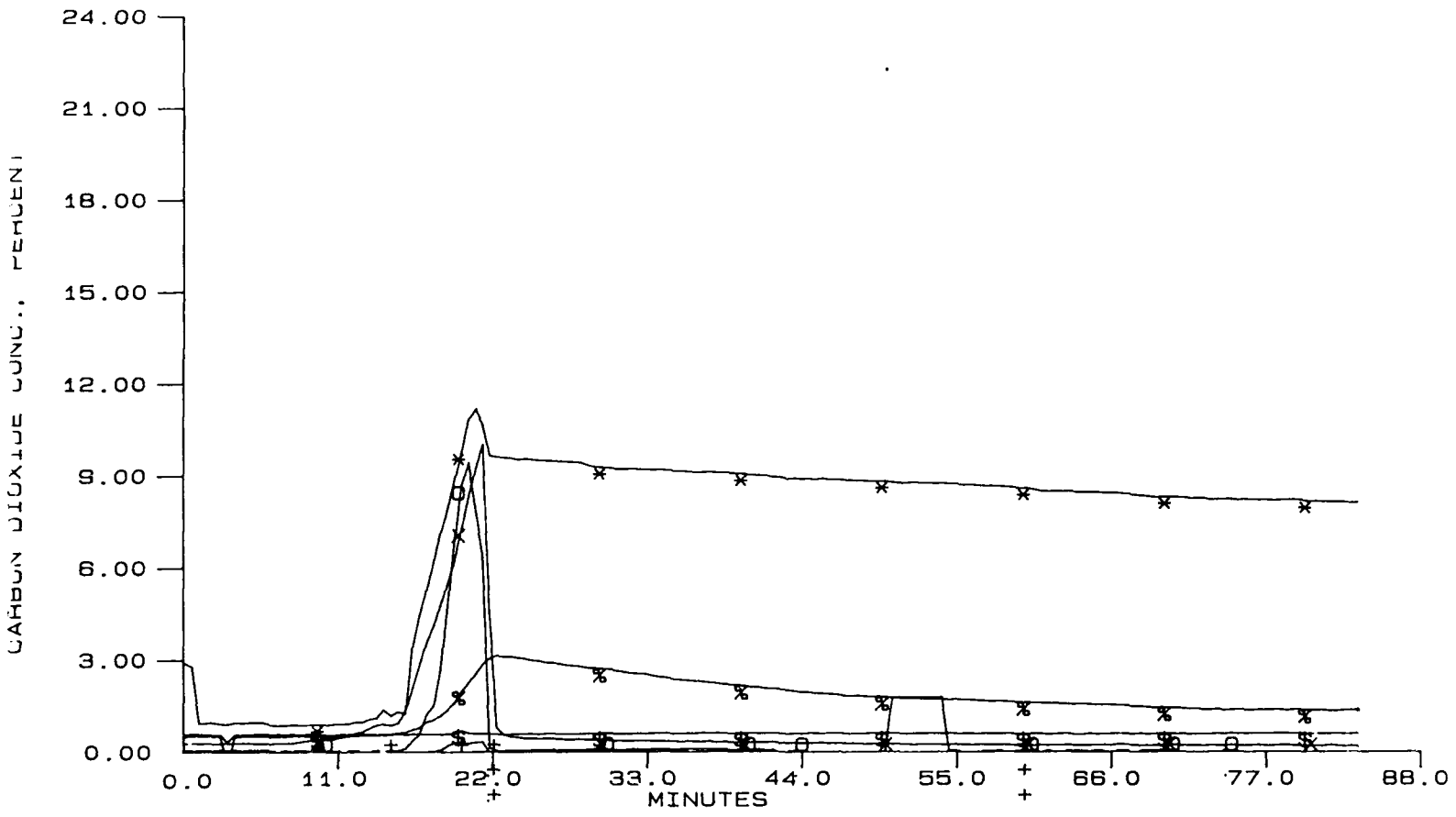


Fig. C-19 Carbon Dioxide Concentrations during Test W-43
SMOKE CURTAIN TEST W-43 ALL DECKS CH 18, 22 X, 26 +, 28 *, 30 $, 32 %, 34 &

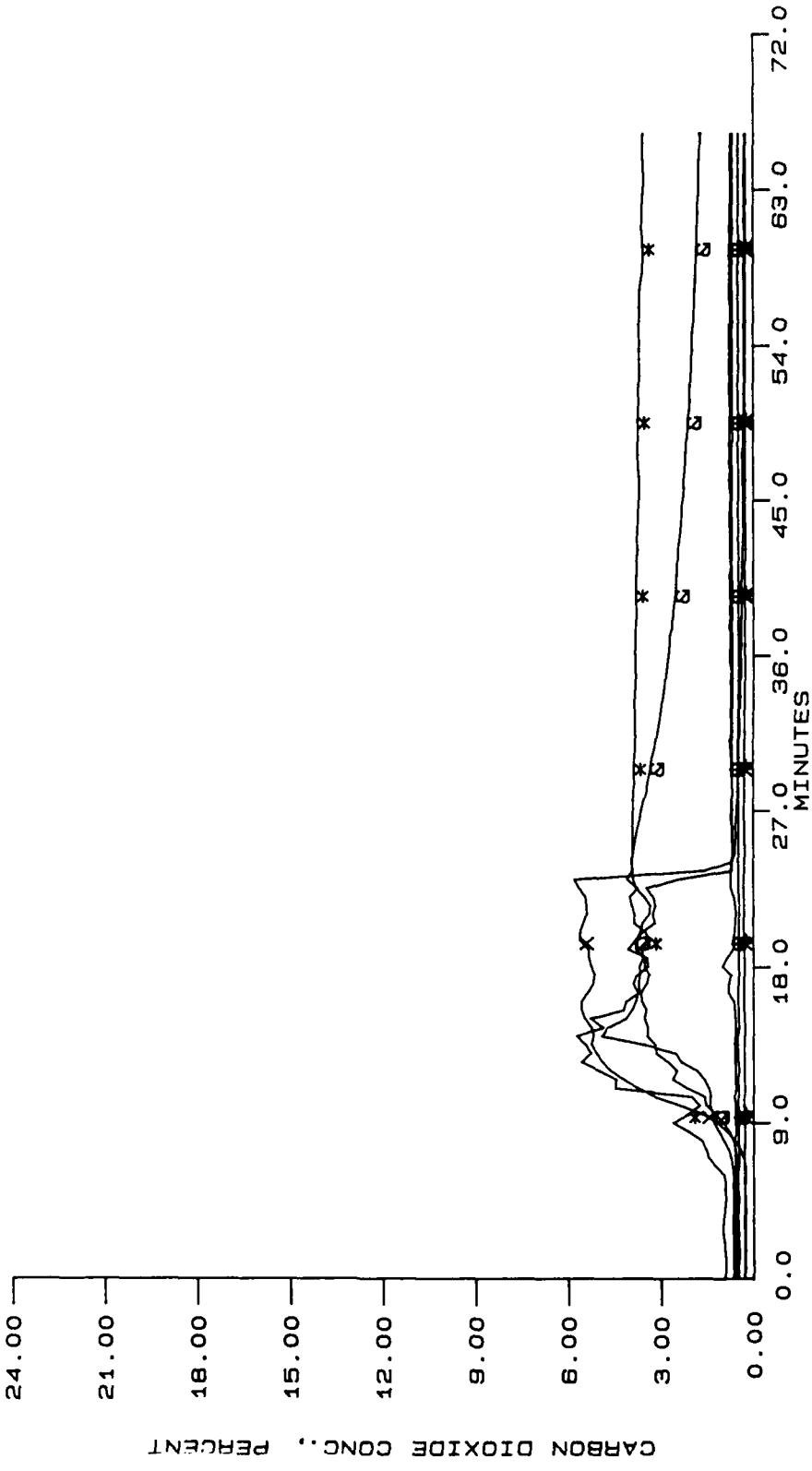


Fig. C-20 Carbon Dioxide Concentrations during Test W-44

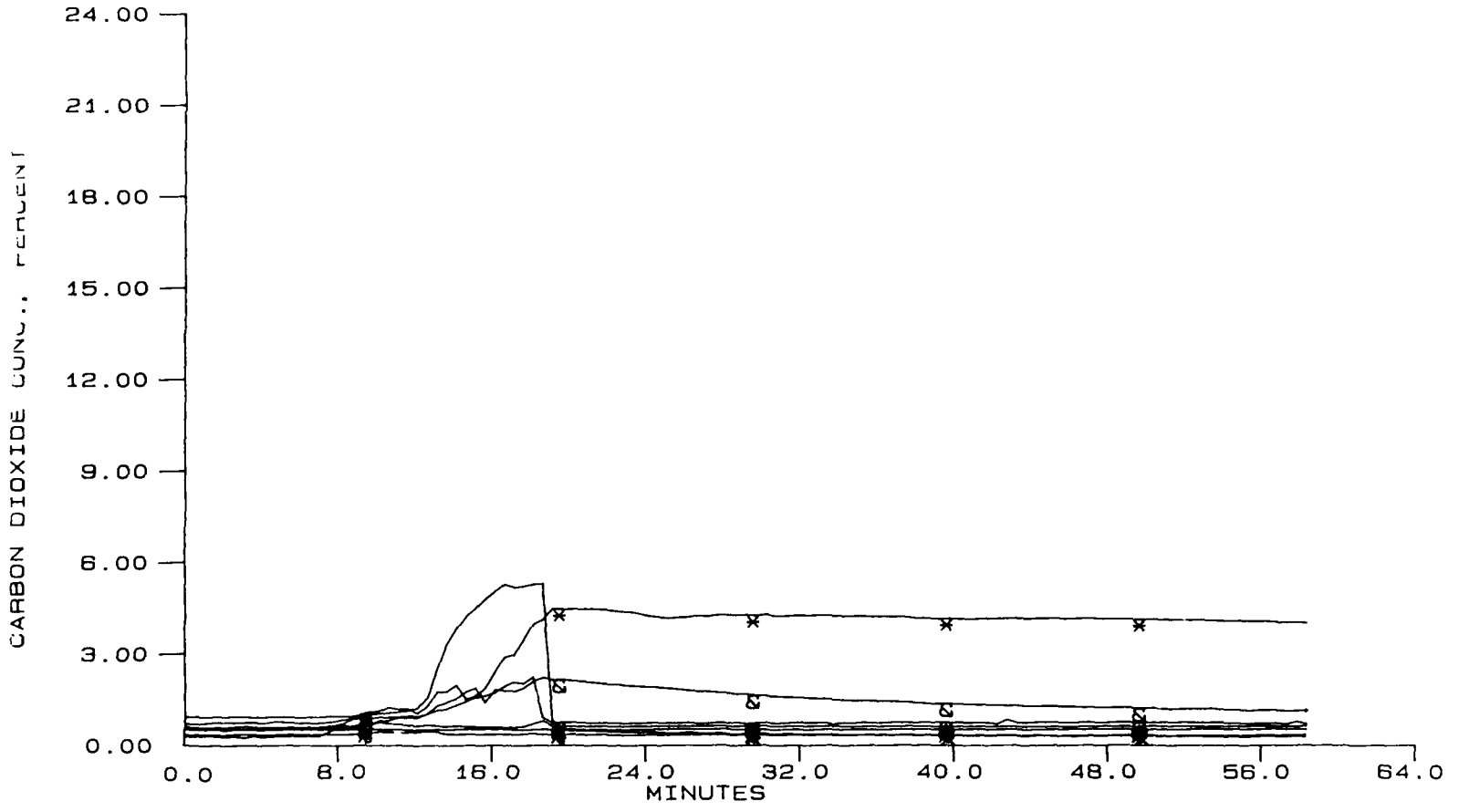


Fig. C-21 Carbon Monoxide Concentrations during Test W-35

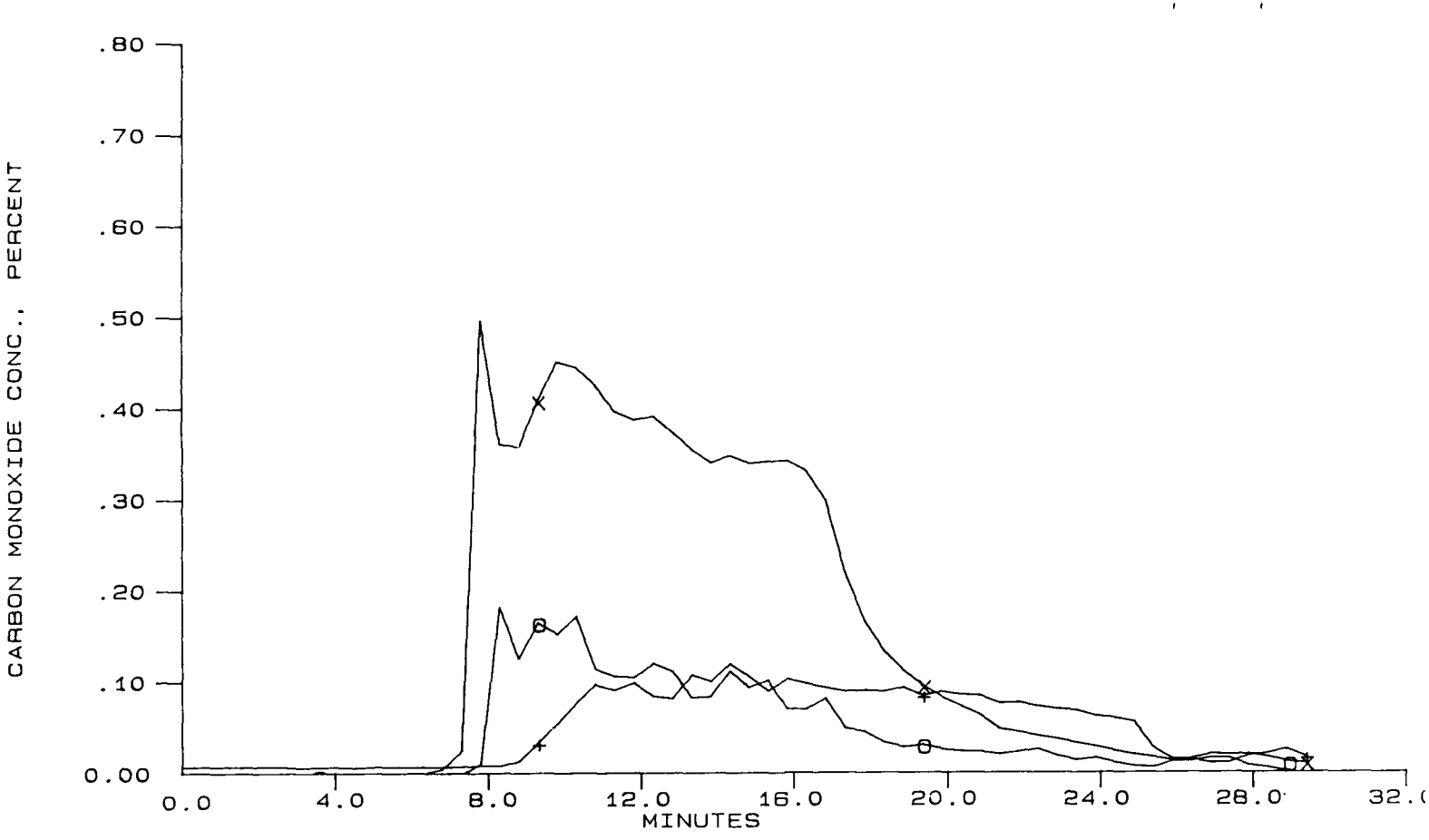


Fig. C-22 Carbon Monoxide Concentrations during Test W-36

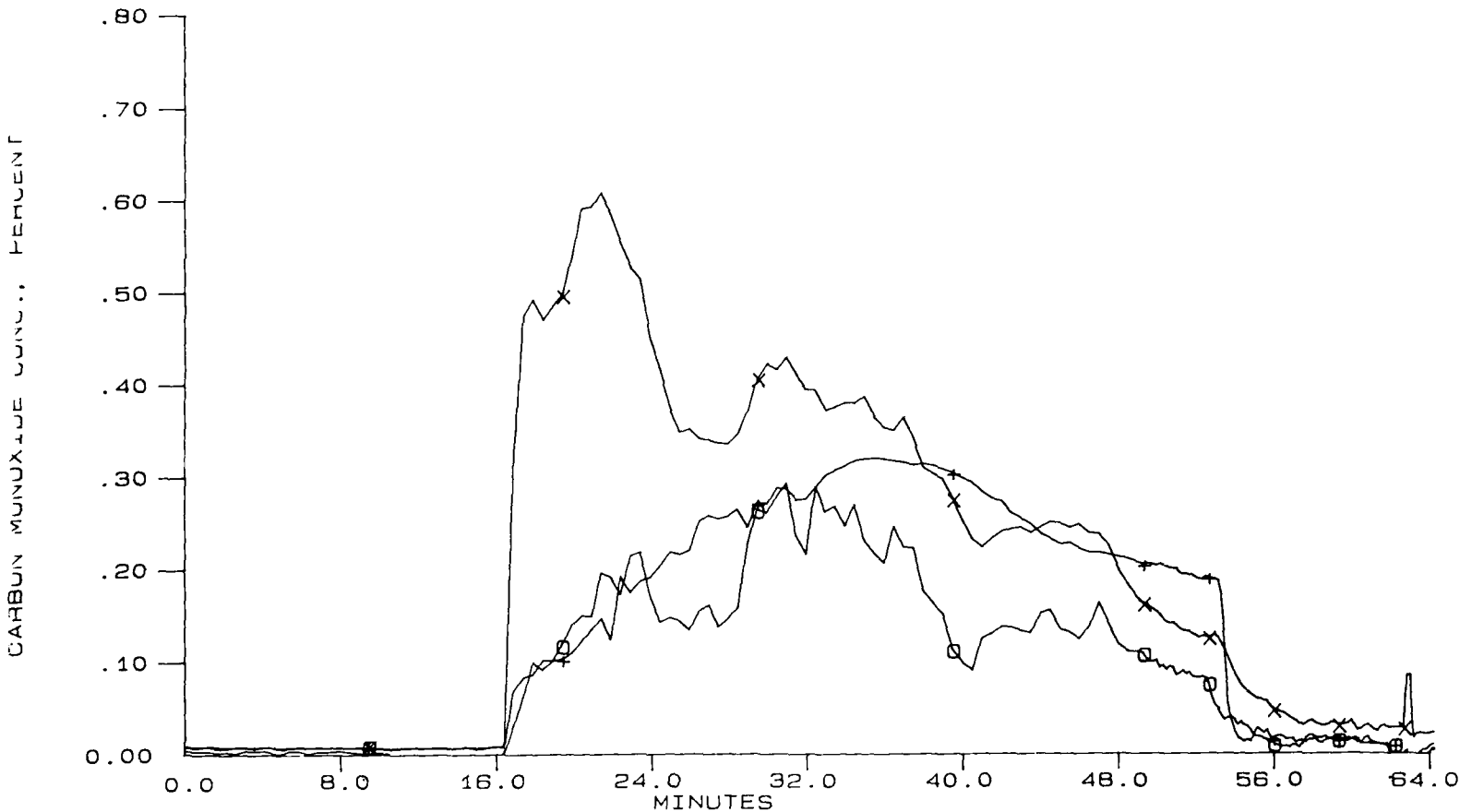


Fig. C-23 Carbon Monoxide Concentrations during Test W-37

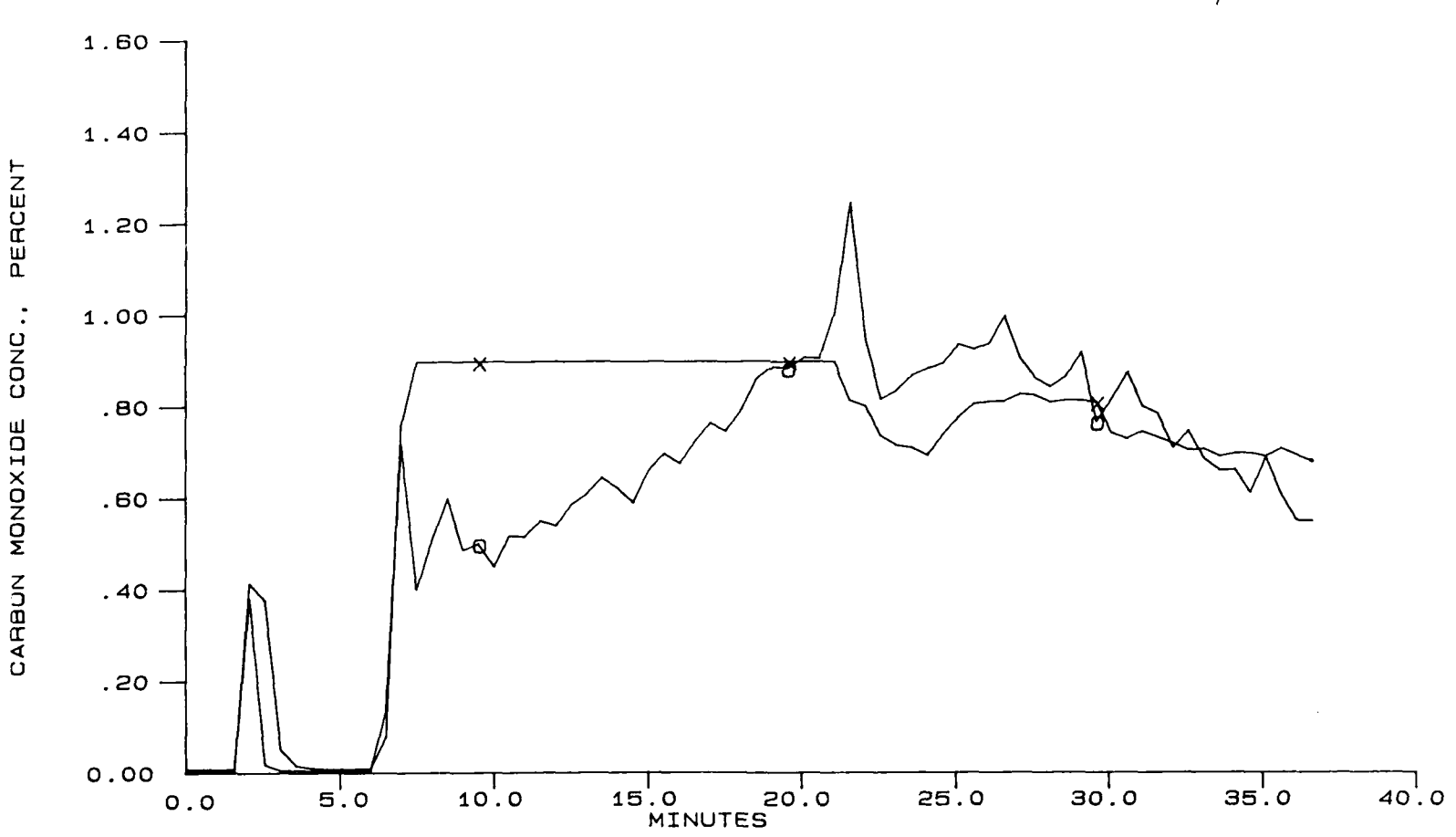


Fig. C-24 Carbon Monoxide Concentrations during Test W-38
SMOKE CURTAIN TEST W-38 LEVEL 01 & MAIN DECK CH 17 O, 21 X, 25 +

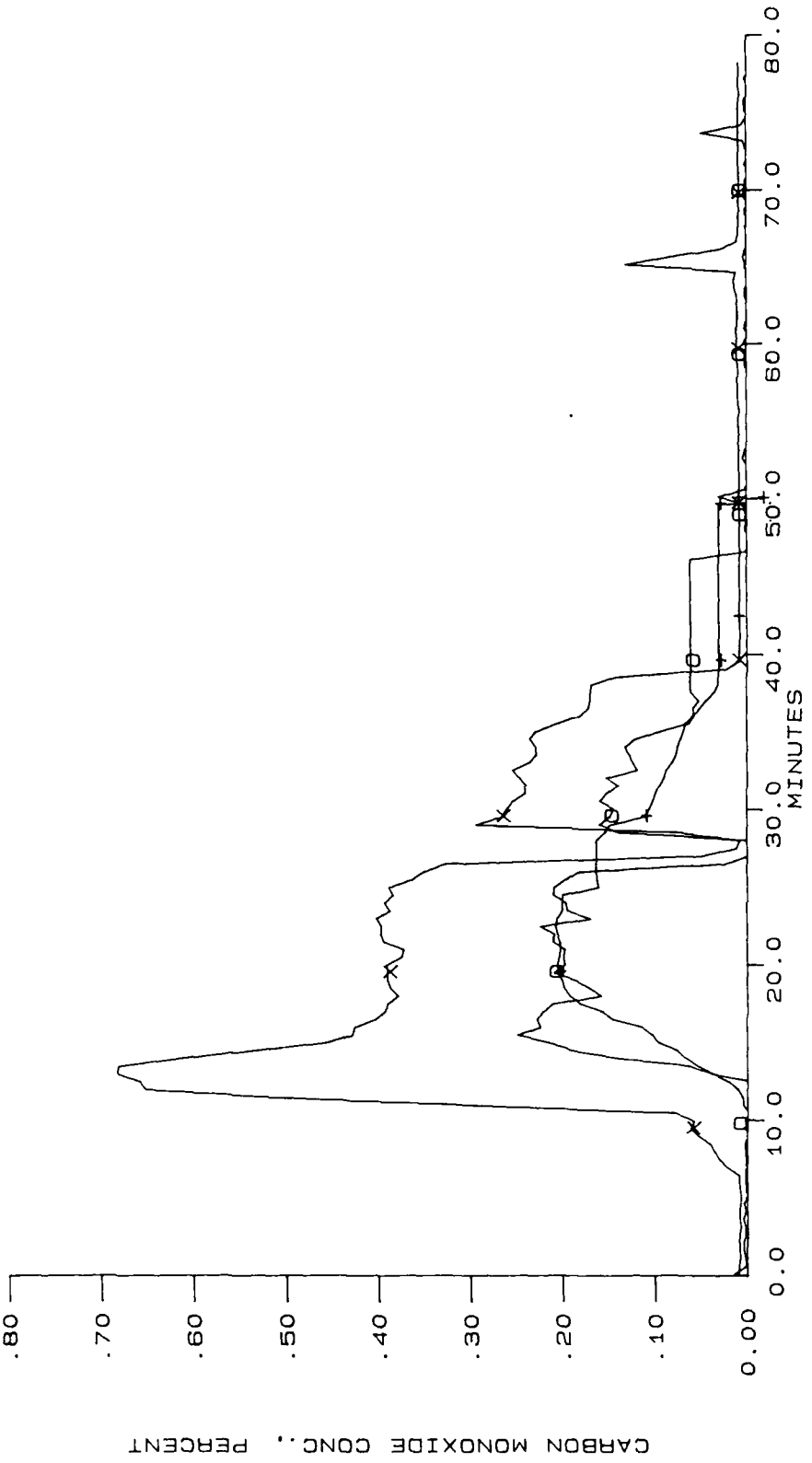


Fig. C-25 Carbon Monoxide Concentrations during Test W-39

SMOKE CURTAIN TEST W-39 LEVEL 01 & MAIN DECK CH 21 C

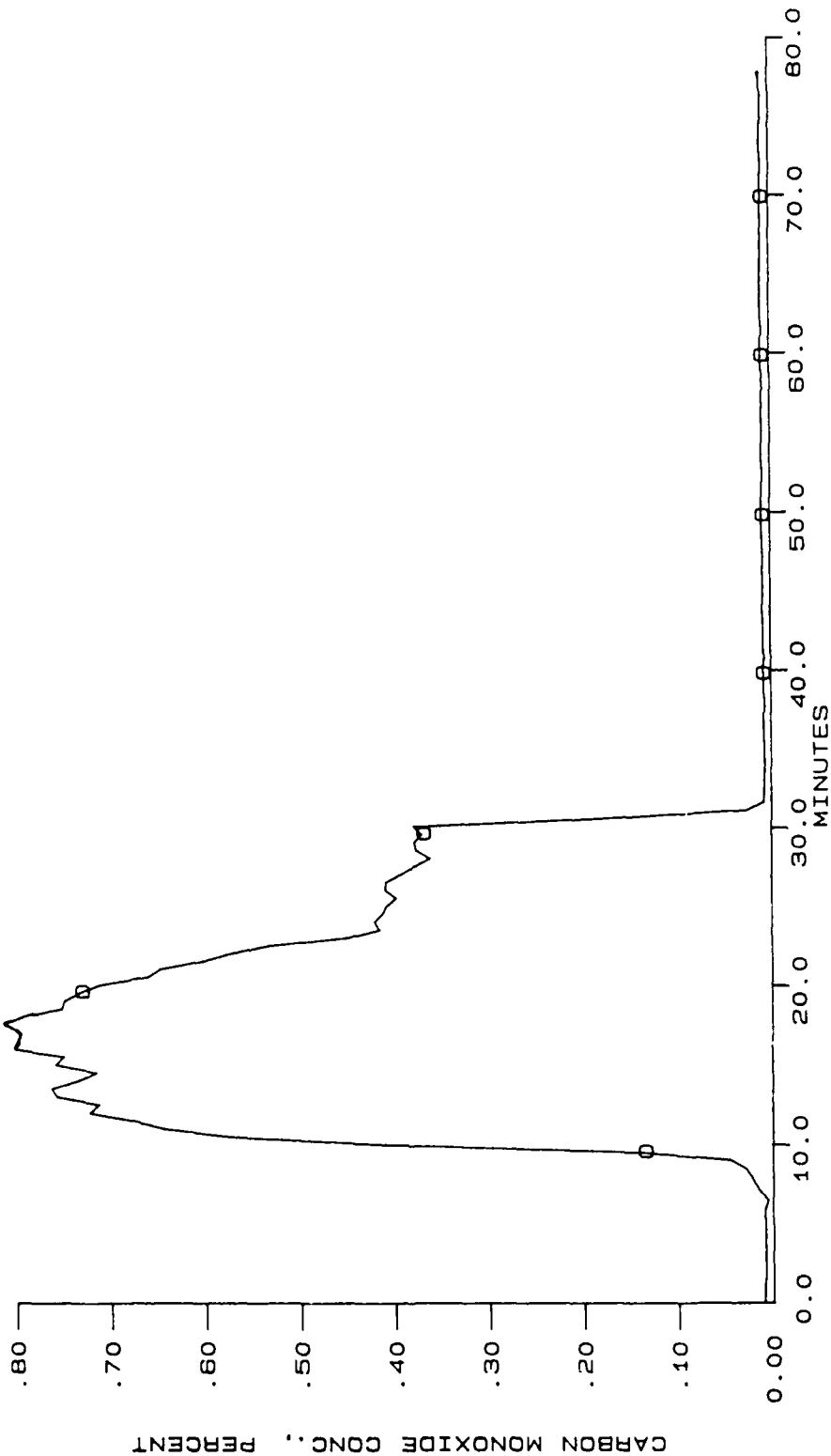


Fig. C-26 Carbon Monoxide Concentrations during Test W-40
SMOKE CURTAIN TEST W-40 LEVEL 01 & MAIN DECK CH 17 O, 21 X, 25 +

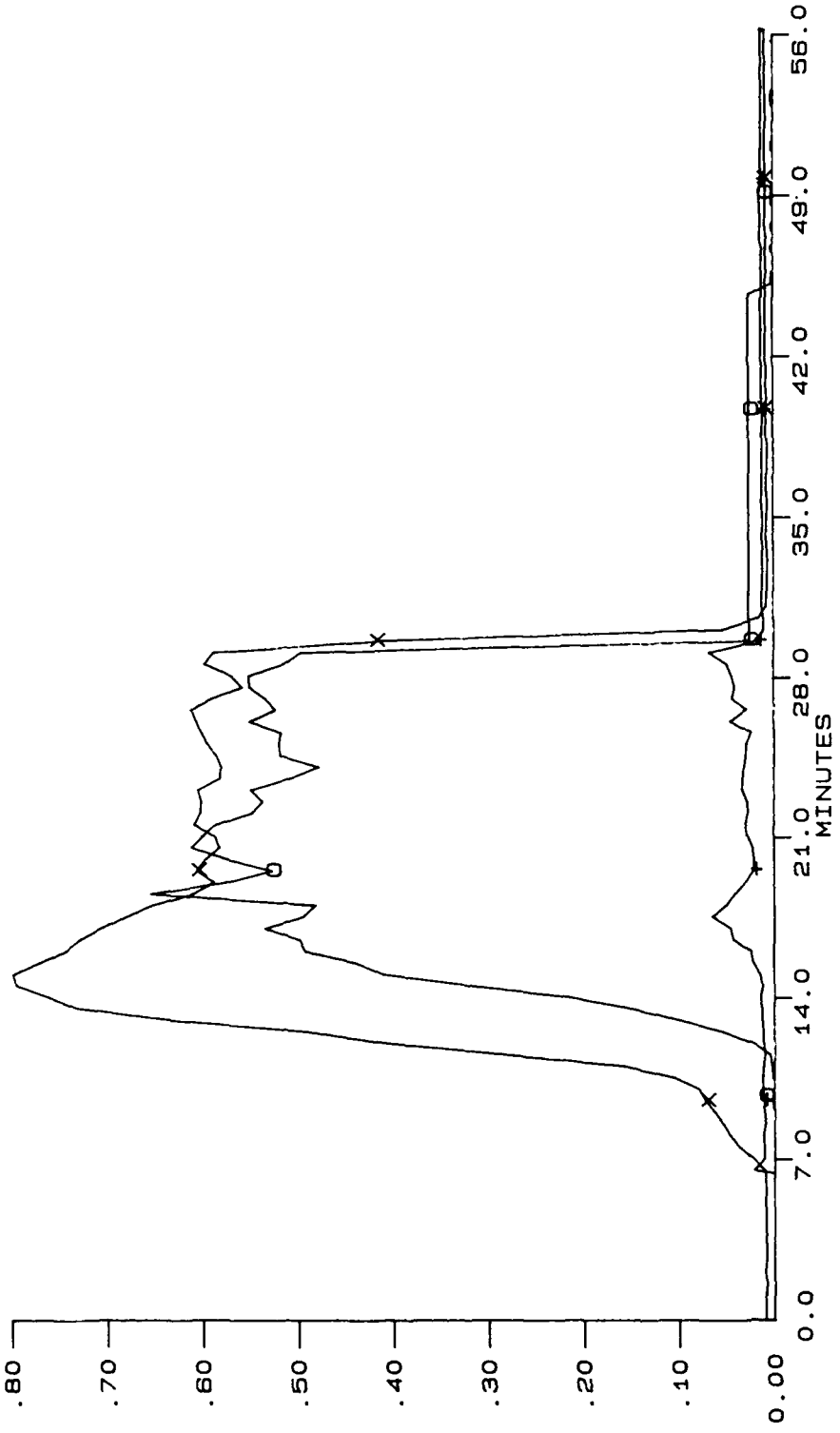


Fig. C-27 Carbon Monoxide Concentrations during Test W-41

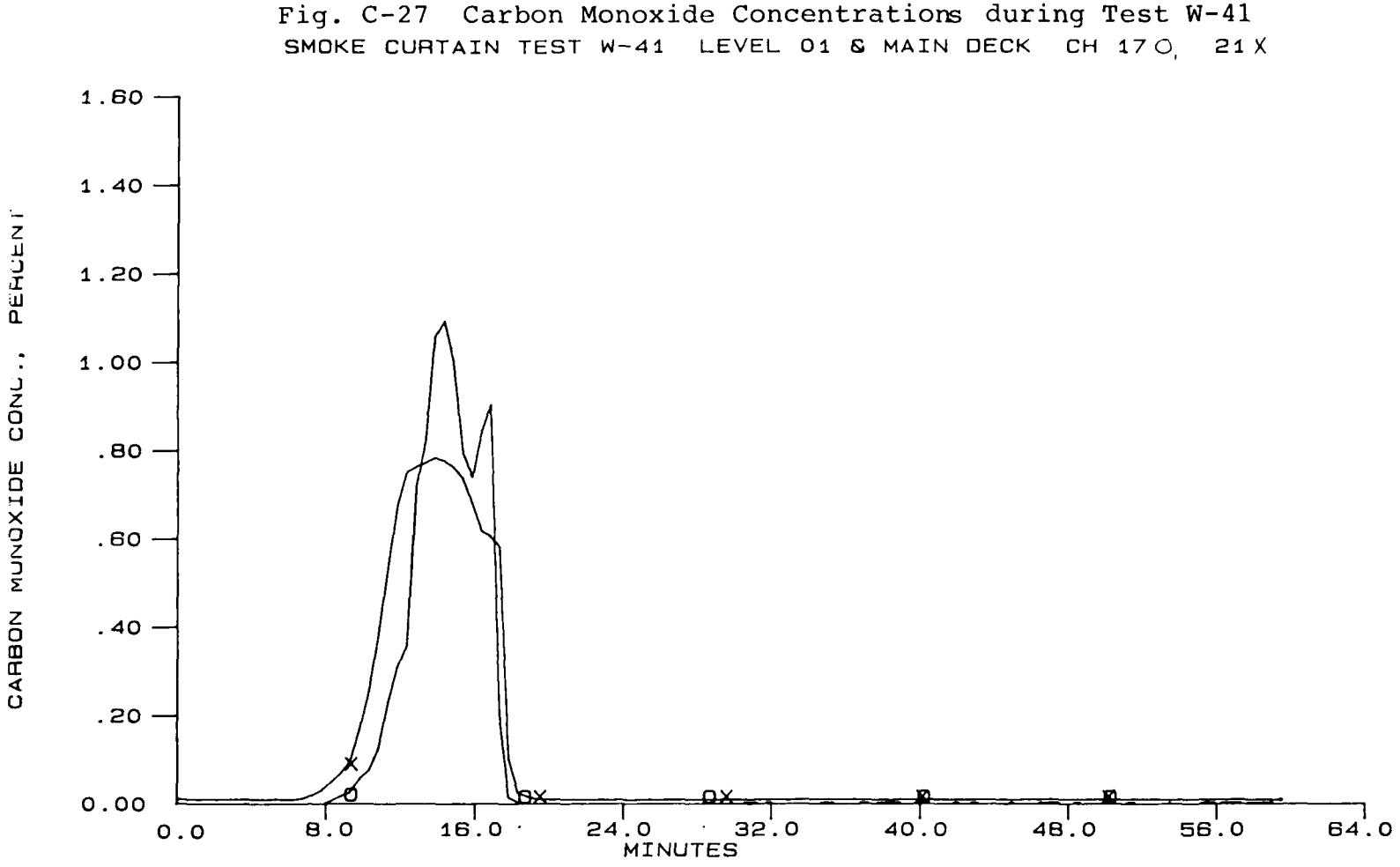


Fig. C-28 Carbon Monoxide Concentrations during Test W-42
SMOKE CURTAIN TEST W-42 LEVEL 01 & MAIN DECK CH 17 O, 21 X

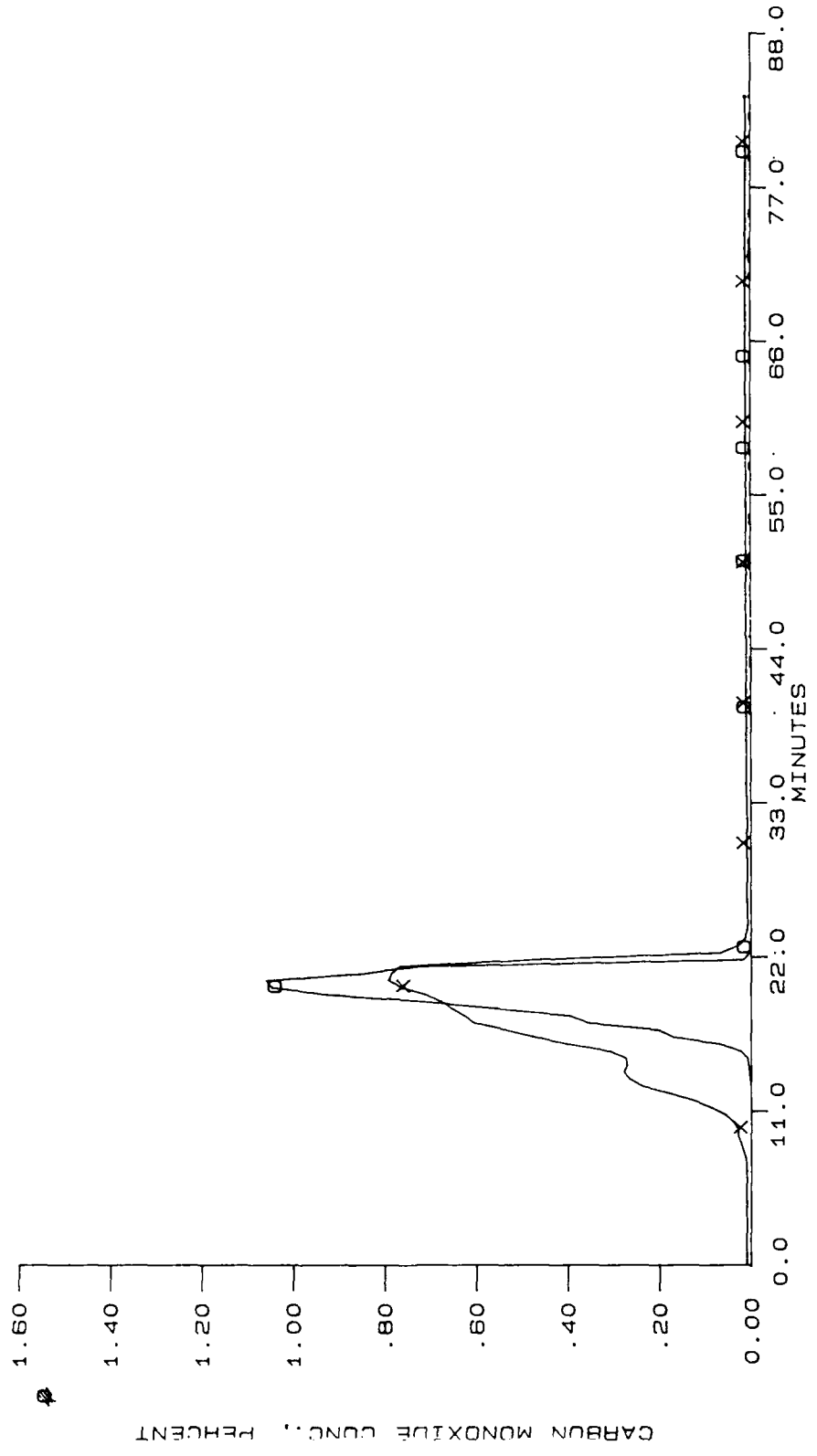


Fig. C-29 Carbon Monoxide Concentrations during Test W-43

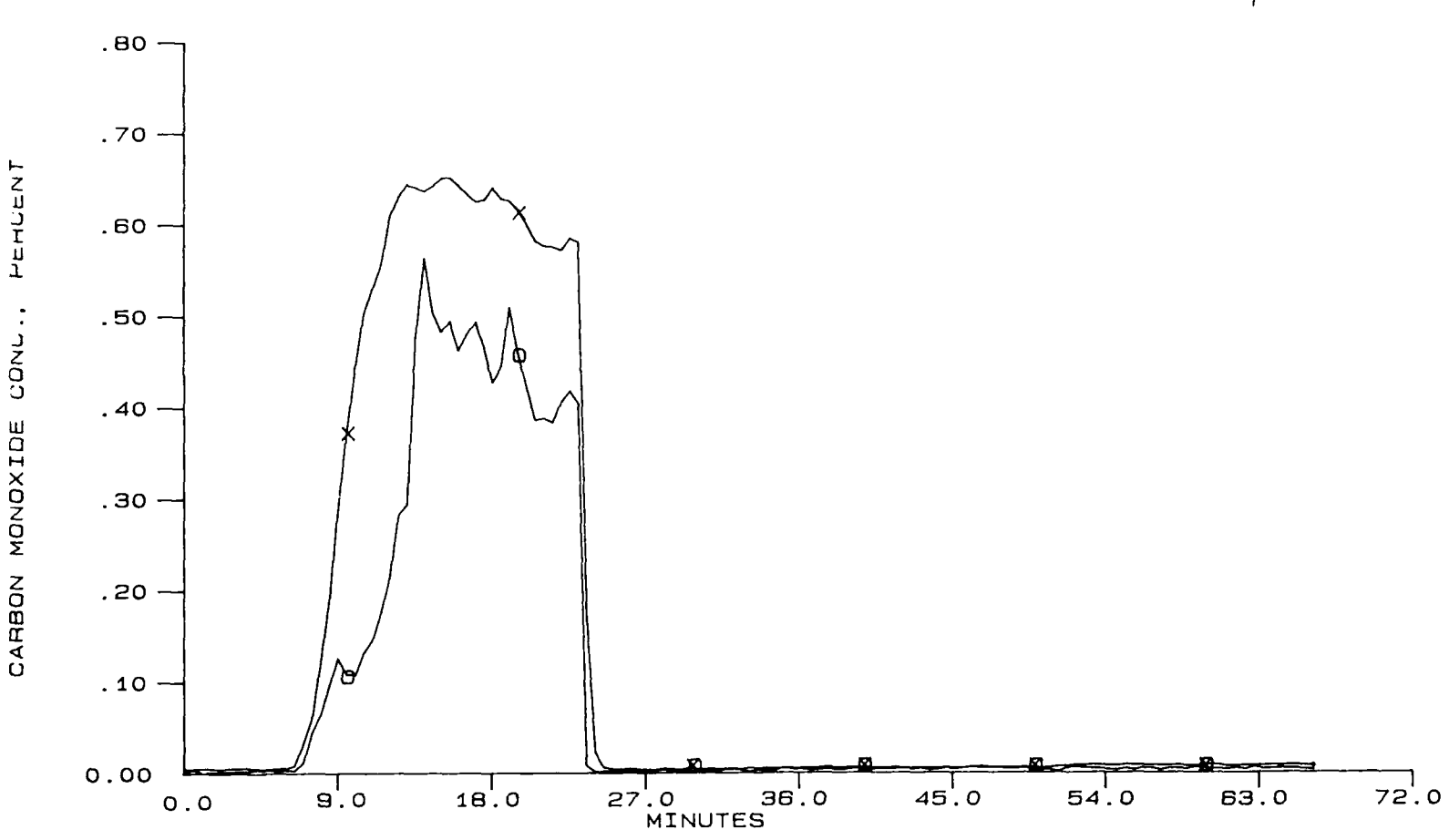
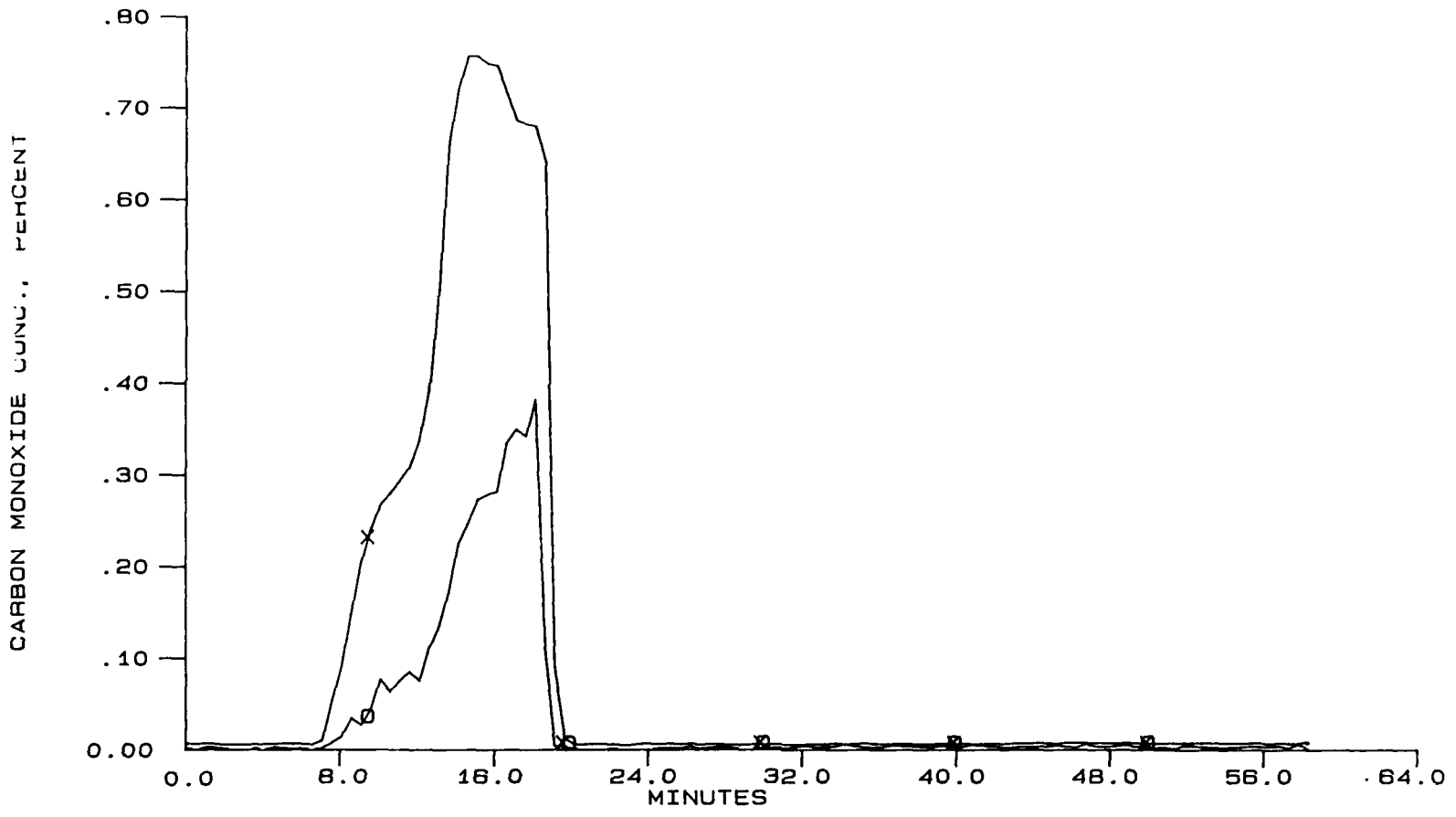


Fig. 30 Carbon Monoxide Concentrations during Test W-44



Appendix D (Photographs from Smoke Curtain Tests)

Each test was documented with video and still pictures. Some representative scenes are presented in this Appendix. Each test was accompanied by a pre-inspection of the test area, photo D-1 and a post fire brief, photo D-2. In some of the tests firefighting, use of smoke curtains and desmoking was carried out simultaneously, photo D-3. The control room was off limits to the fire fighters and scene leaders. This was necessary as the IR camera (NIFTI) gave complete views of the fire fighting efforts. Allowing the scene leader access to this would have biased the data. The USS SPRUANCE DCA was able to observe all the mistakes of his fire parties, but could not correct them in real time, photo D-4. Typical fire scenes are shown in photo D-5 through D-7. Photo D-8 is "chow call." The wood crib burned in Test W-36 is pictured in photo D-9.

The main deck thwart ships passage way is shown in photo D-10. The numbers and lights were used in conjuction with the video to determine to determine smoke density. The smoke curtain (blanket) is for inclined ladders is shown from below in this main deck thwart ships passage way, D-11.

The 01 level where most of the activity took place and where the fires were located is shown in photos D-12 through D-22. The 02 level where most of the smoke migrated rapidly is shown in photos D-23 through D-30.

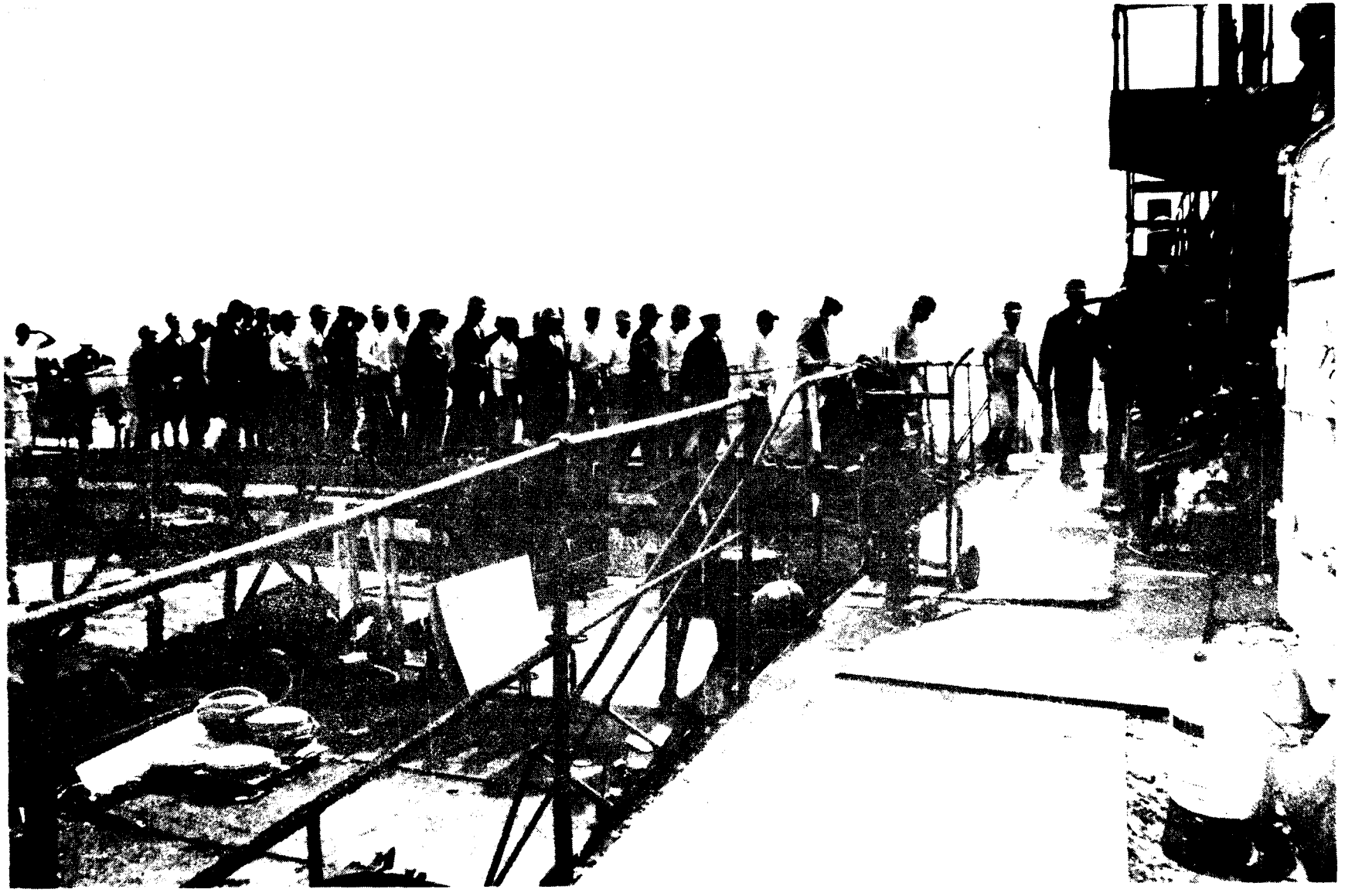


Fig. D-1 Almost the whole crew of the USS SPRUANCE participated in these tests. Each test was preceeded by an inspection of the fire area by the repair parties participating in the tests.

Fig. D-2 Each test was followed by a debrief by the DCA of USS SPRUANCE, Lt(Jg) Michael Brown, USN and Mr. Terrance Toomey of Hughes Associates.

Fig. D-3 In tests such as W-44 fire fighting, smoke curtains and simultaneous desmoking was performed.

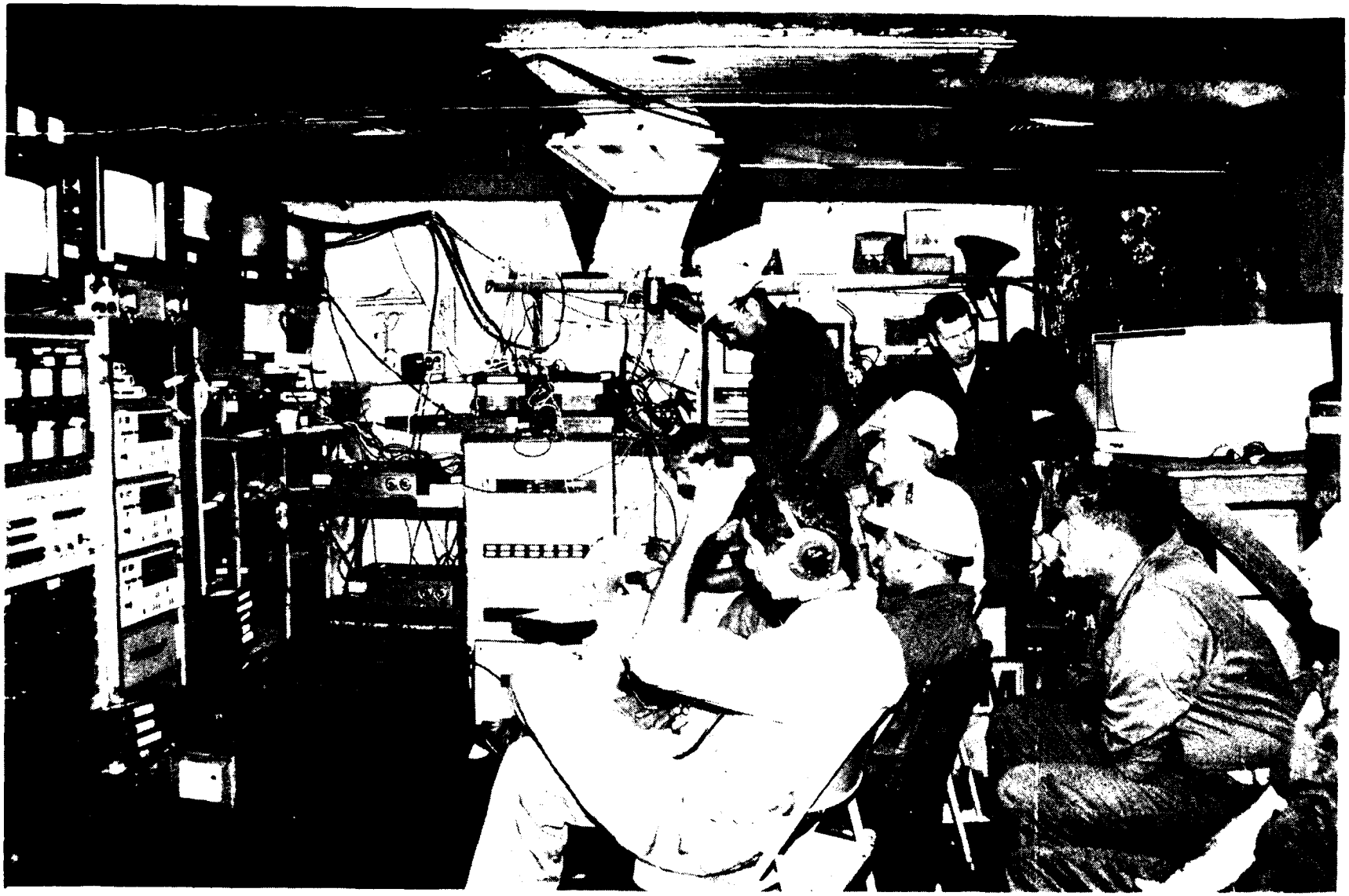


Fig. D-4 The control room gave a unique perspective into the fire fighting tests. The IR cameras (NFTI) allowed seeing through smoke.

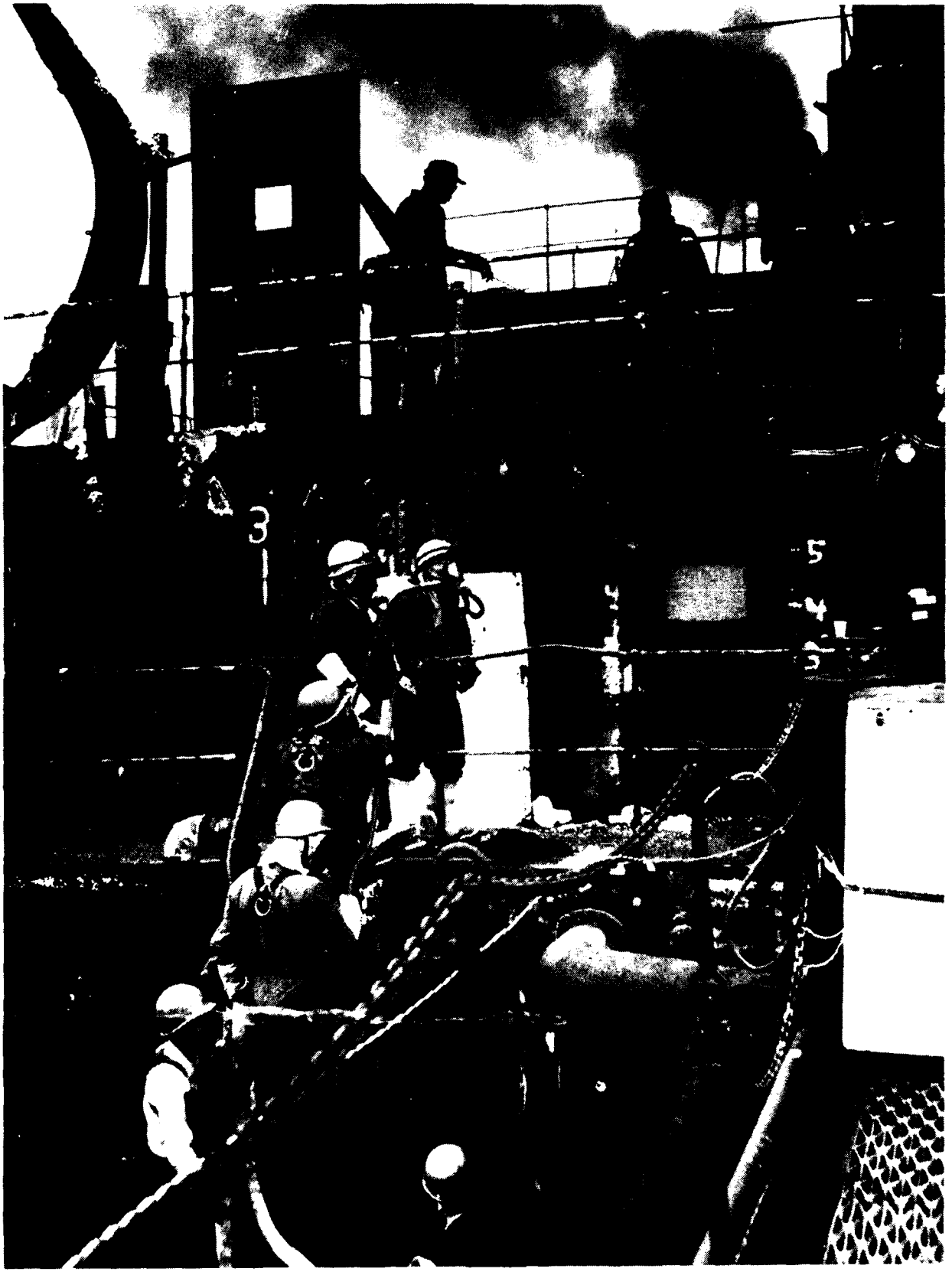


Fig. D-5 Smoke is coming from the starboard passage on the 02 level. A fire party is waiting to attack on the 01 level starboard side.

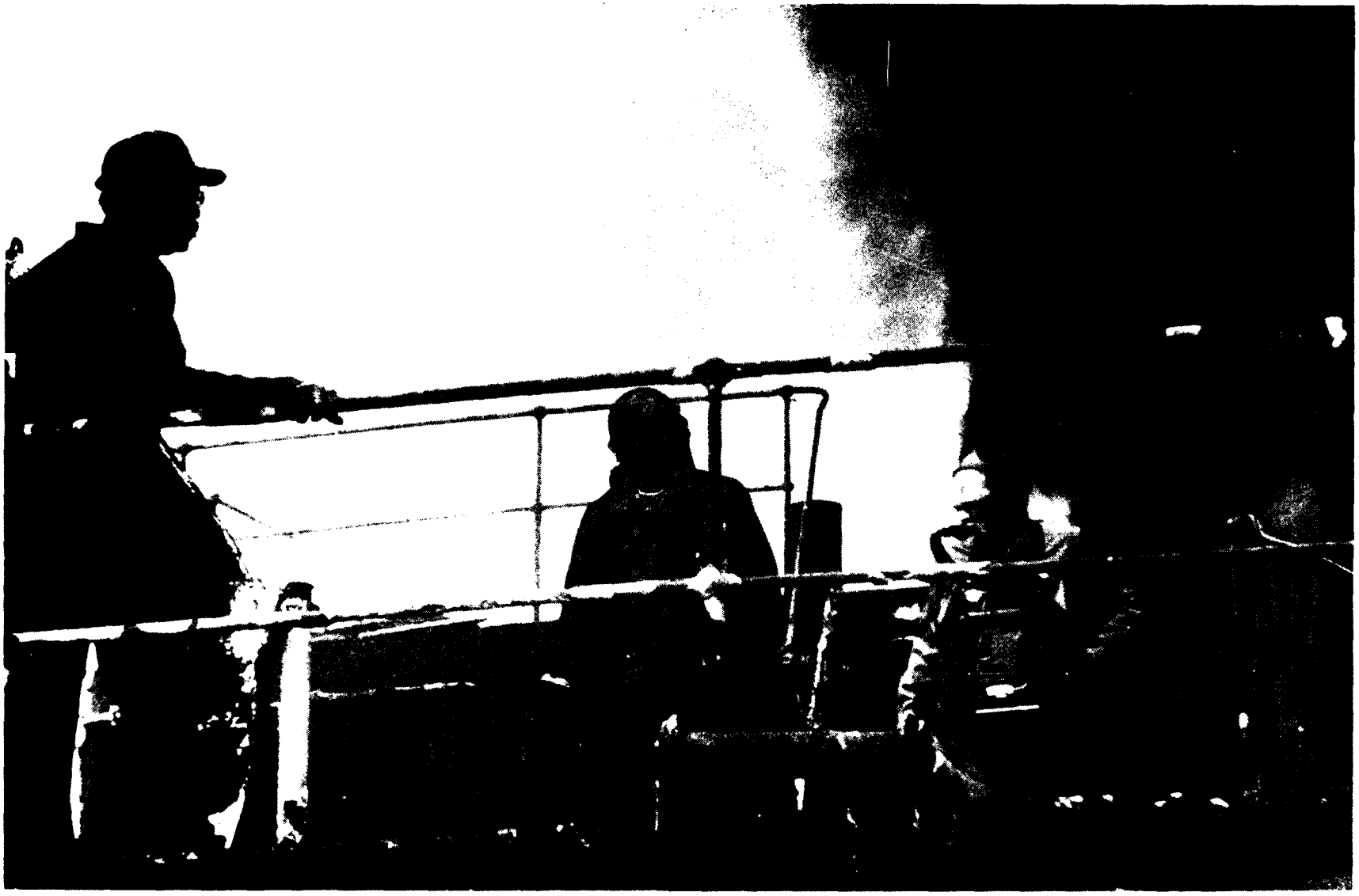


Fig. D-6 The fires for these tests were produced from electrical cables and tires. This view is from 02 level starboard side.

Fig. D-7 "One Tired Ole Fire Fighter" The DCA, scene leader and Mr. Toomey go over doctrine utilized for the test.

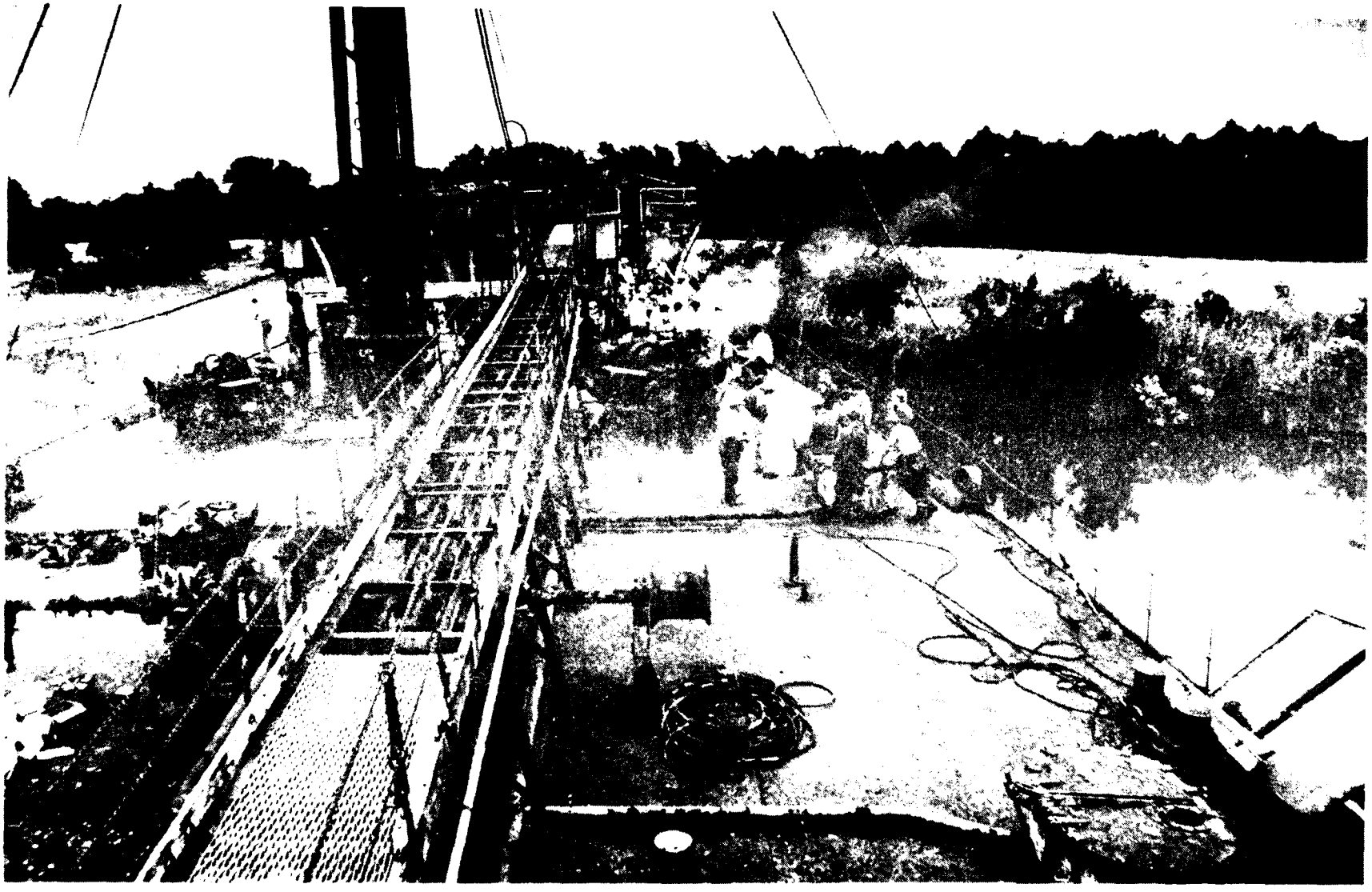


Fig. D-8 "Chow Time"

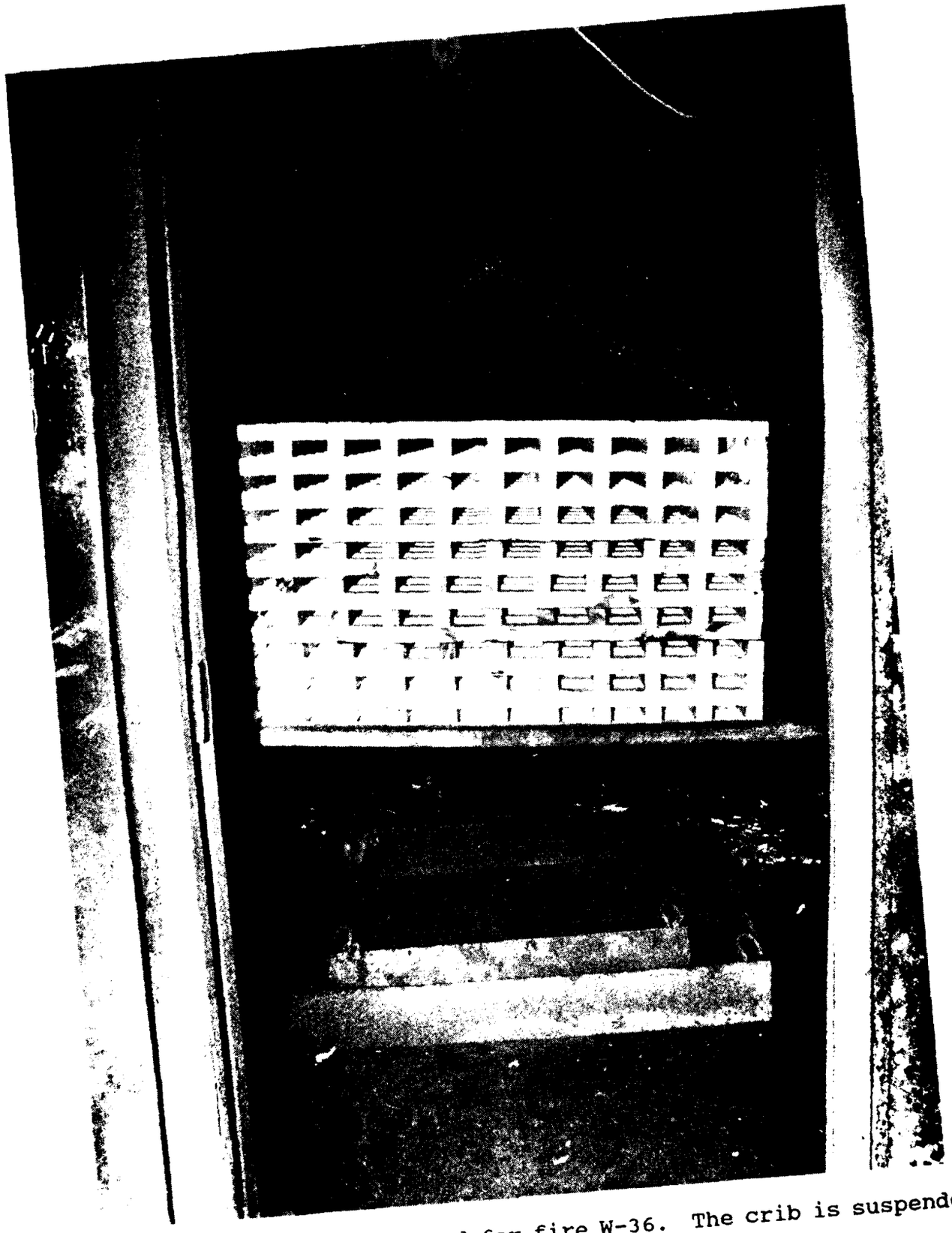


Fig. D-9 Wood crib used for fire W-36. The crib is suspended from a load cell.

Fig. D-10 Thwart ships passage way on the main deck. The numbers and lights were used to measure obscuration.

Fig. D-11 Thwart ships passage way main deck inclined ladder to 01 level. The smoke curtain. Blanket is deployed over the ladder.

Fig. D-12 01 level starboard side. Numbers, lights and archway are visible. The archway was made of wood with a metal lip. This photo is looking aft.

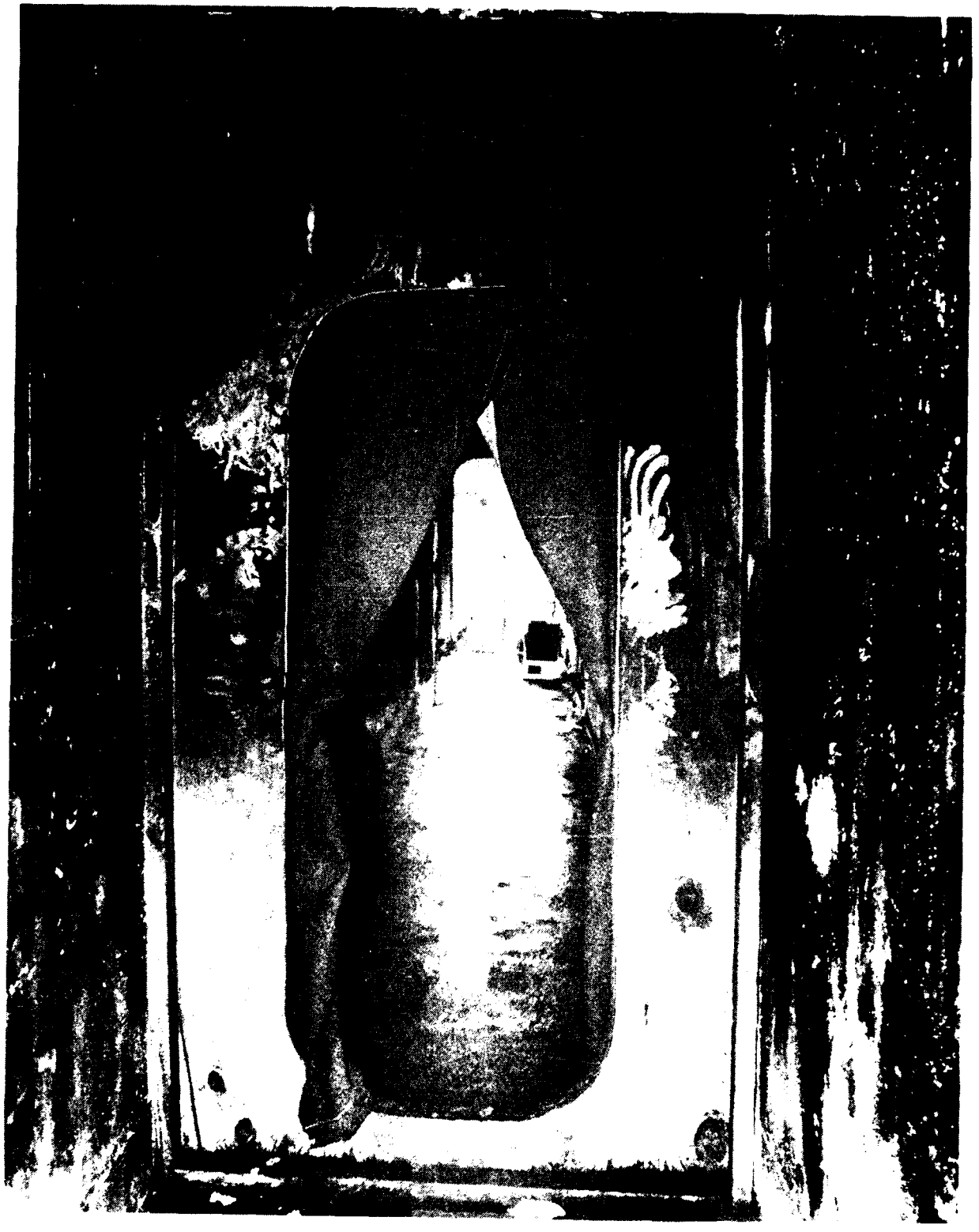


Fig. D-13 A closer view of archway on 01 level starboard side with a smoke curtain deployed. The curtain is single piece type with overlapping panels.

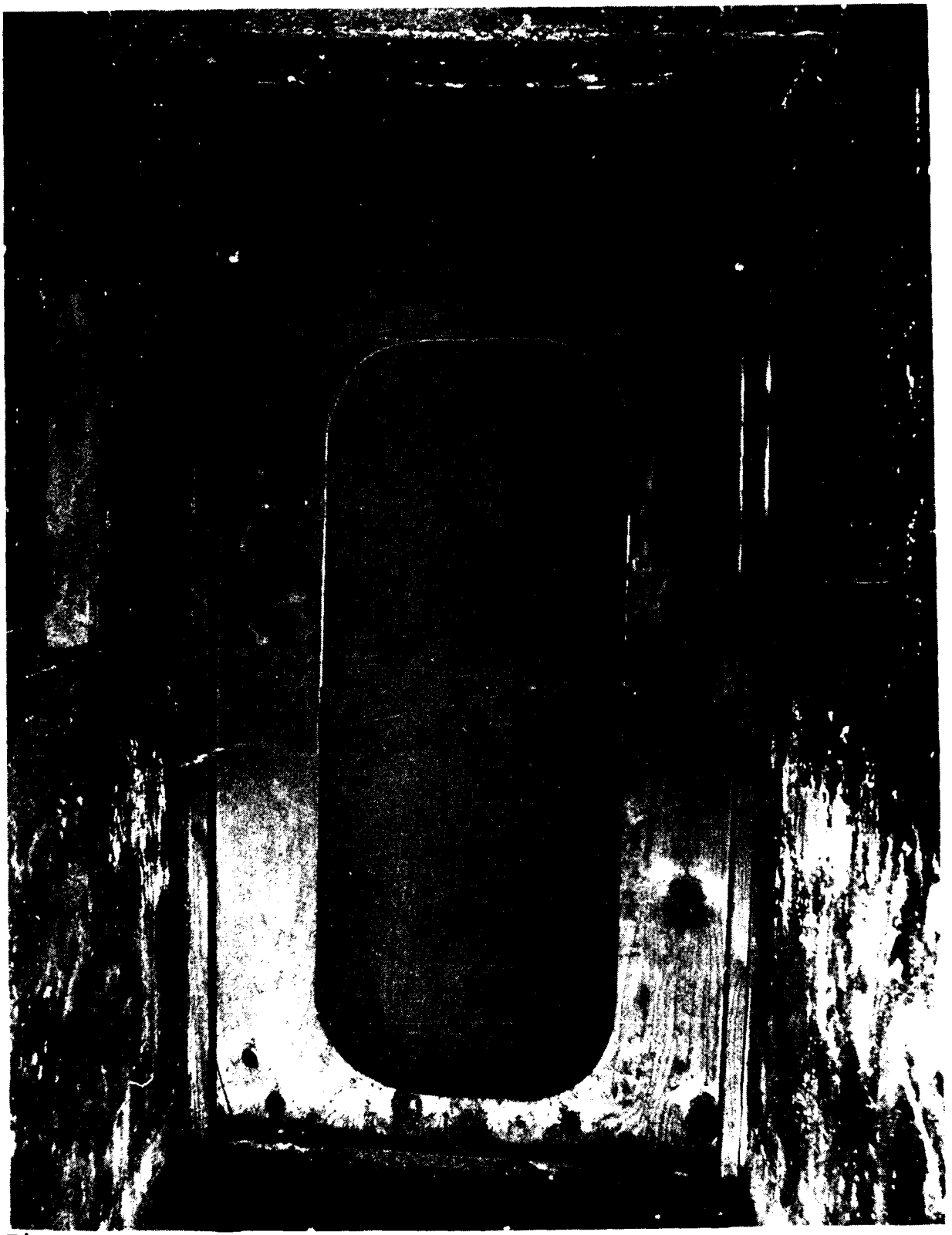


Fig. D-14 The curtain in D-13 is allowed to fall in place, chains on the bottom of the curtain keep the panels overlapped.

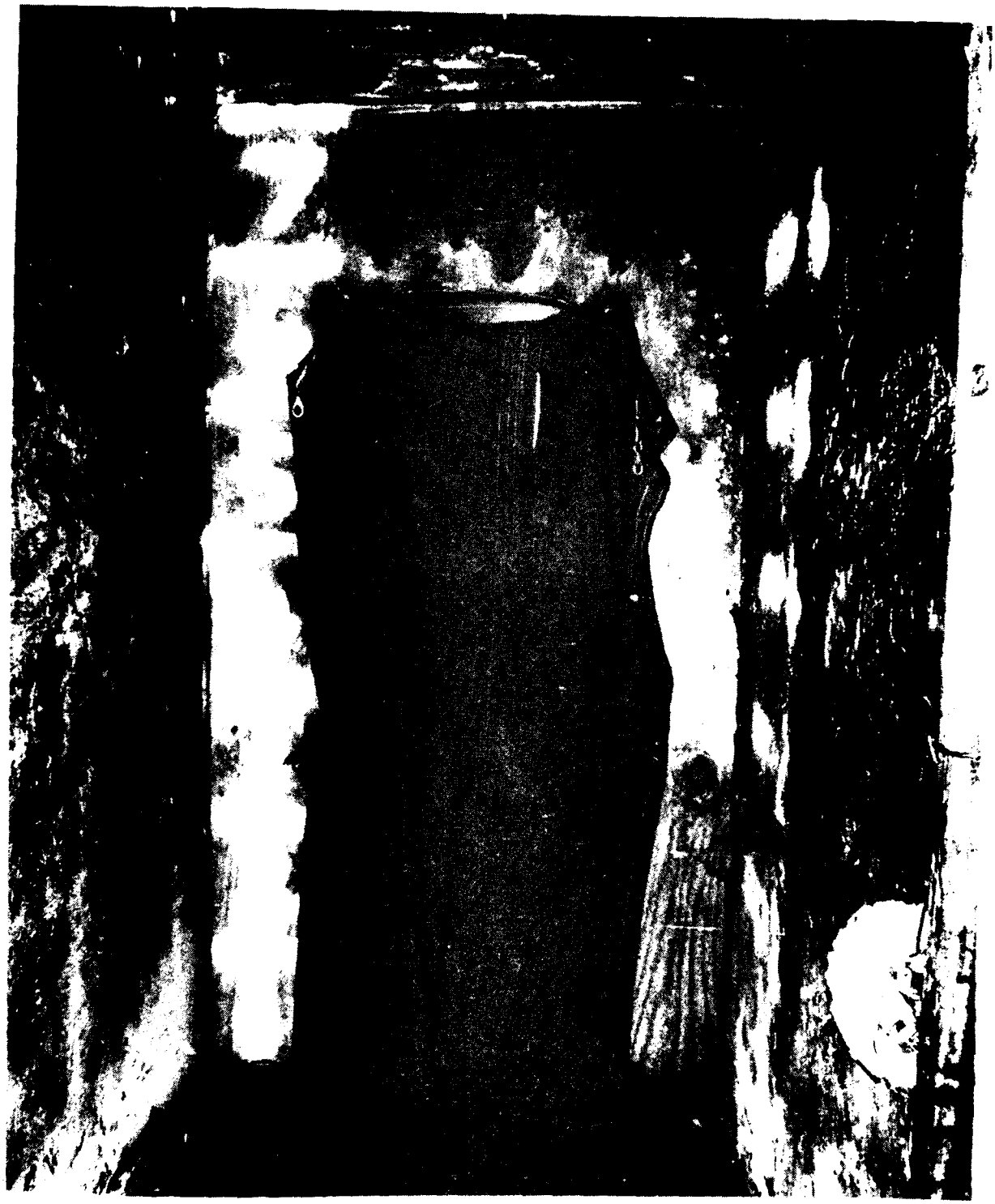


Fig. D-15 01 level starboard passage - This smoke curtain was deployed during a test. The hot gas cloud in the overhead and the inability to see made getting a complete fit difficult. The gap in the top allowed smoke to escape. Vice grips were used as curtain clamps.

Fig. D-16 01 level starboard passage - unrehearsed use of smoke curtain does not work. This was the first attempt to deploy the smoke curtain during a fire. The job was incomplete and on the wrong opening.

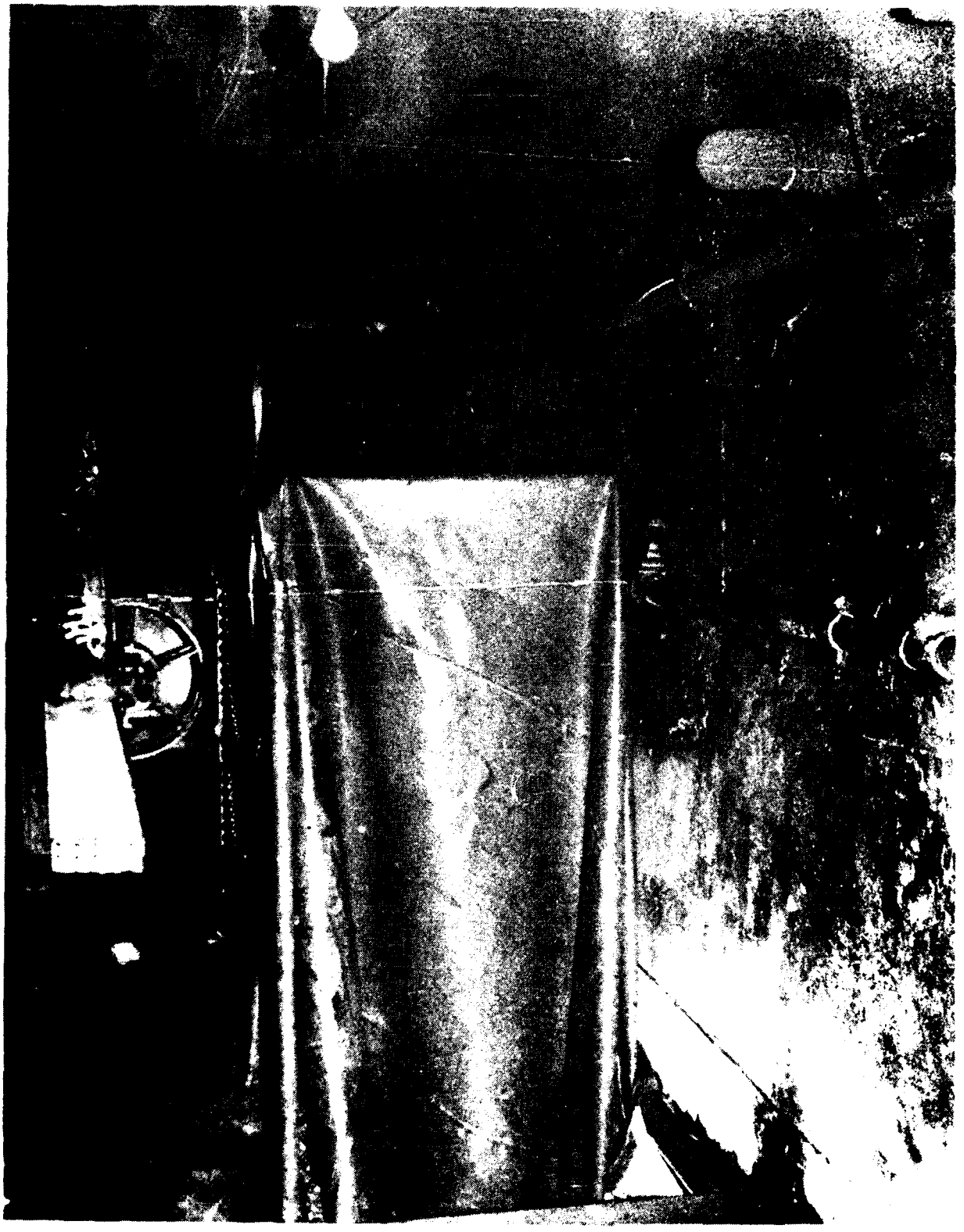


Fig. D-17 01 level thwart ships passage way - Smoke curtain (blanket) deployed on 01 level over the inclined ladder going to the main deck. See photo D-11 also.

Fig. D-18 01 level thwart ships passage way - The smoke curtain (blanket) was deployed from the 02 level over the inclined ladder from 01 to 02 level.

Fig. D-19 01 level thwart ships passage way - The smoke curtain in another test was deployed similar to D-18 photo.

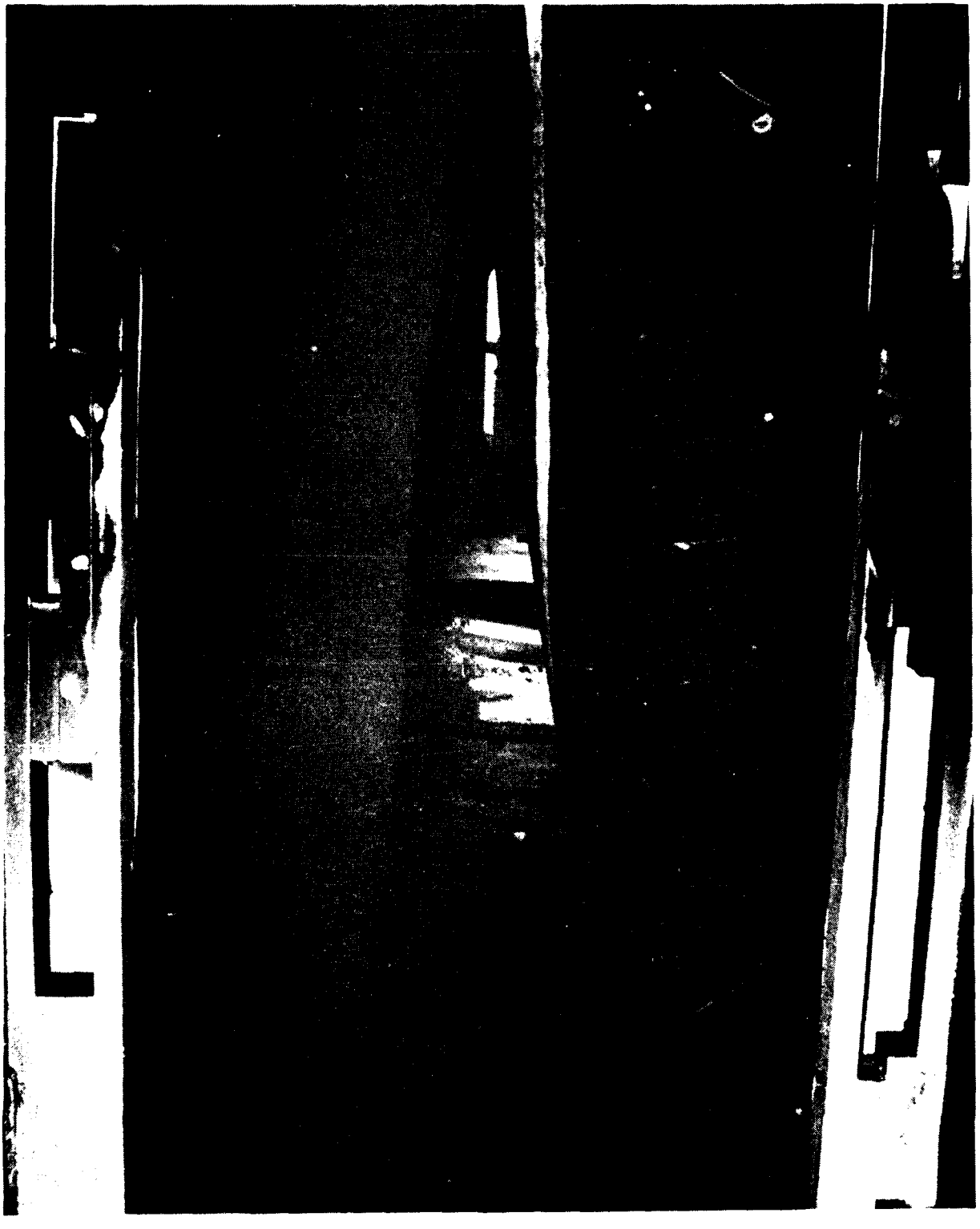


Fig. D-20 01 level port passage - Smoke curtain was used to keep smoke from coming down this passage and getting into the control room. This is a split panel single piece curtain.

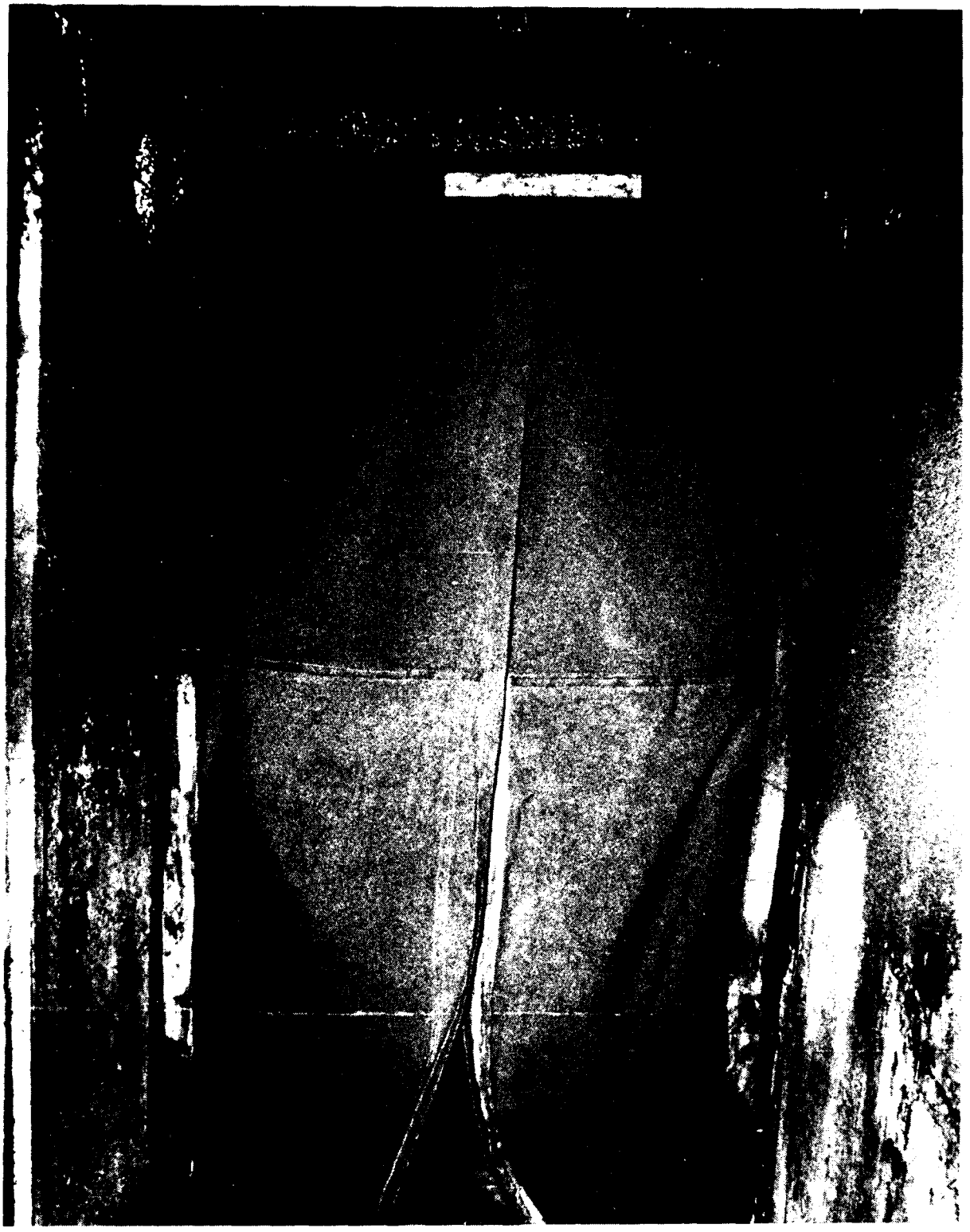


Fig. D-21 01 level port passage - This is the other side of the curtain shown in D-20. A Velcro strip was used to seal the curtains.

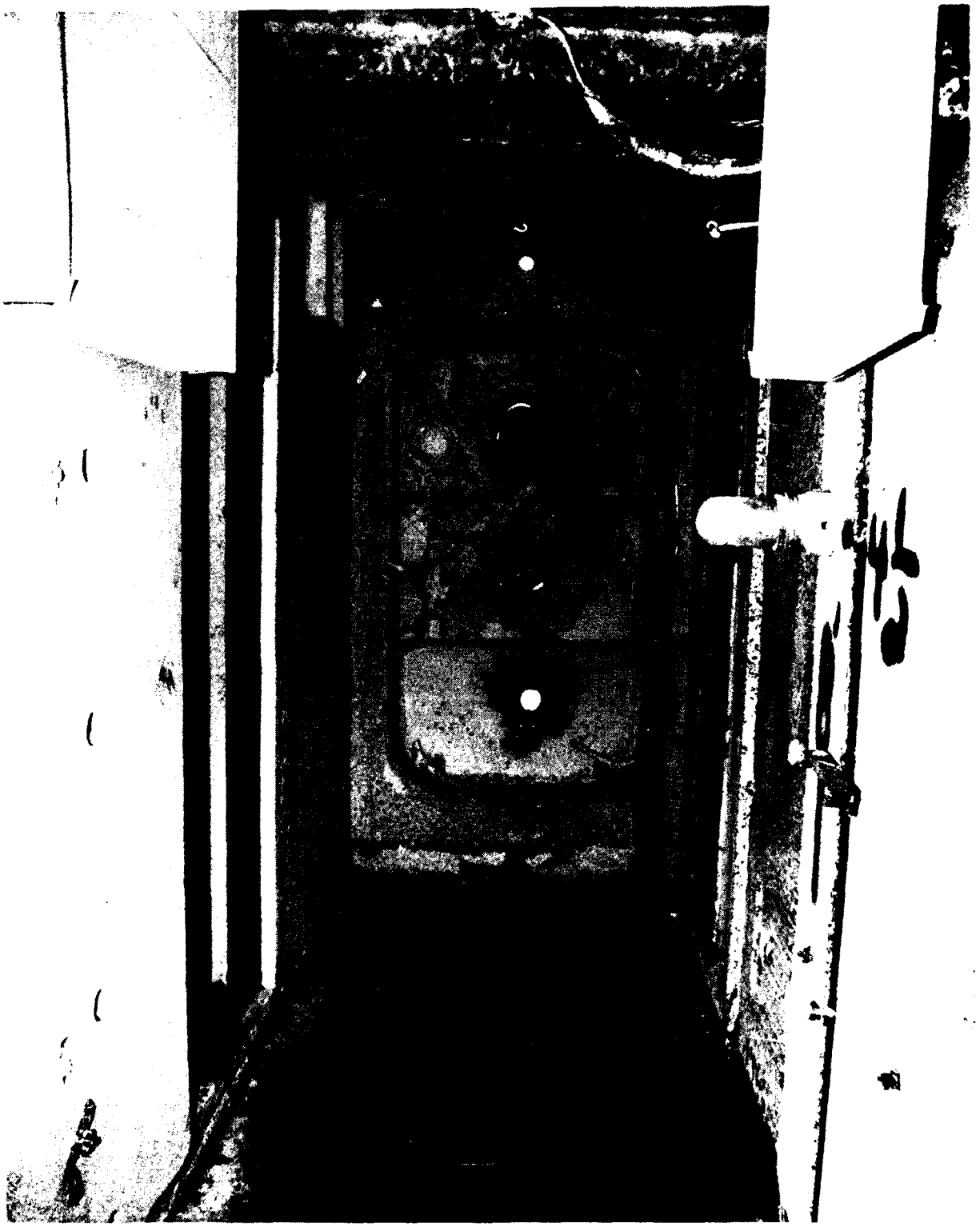


Fig. D-22 01 level port side - This is the passage way on both the inboard and outboard sides where the fire rooms were. The fire fighters were not told where the fires were located.

Fig. D-23 02 level starboard side. Mr. Cary of David Taylor Research Center is securing a smoke curtain, single piece. This curtain simply drops in front of the door and is pre-hung. Deployment is very rapid.

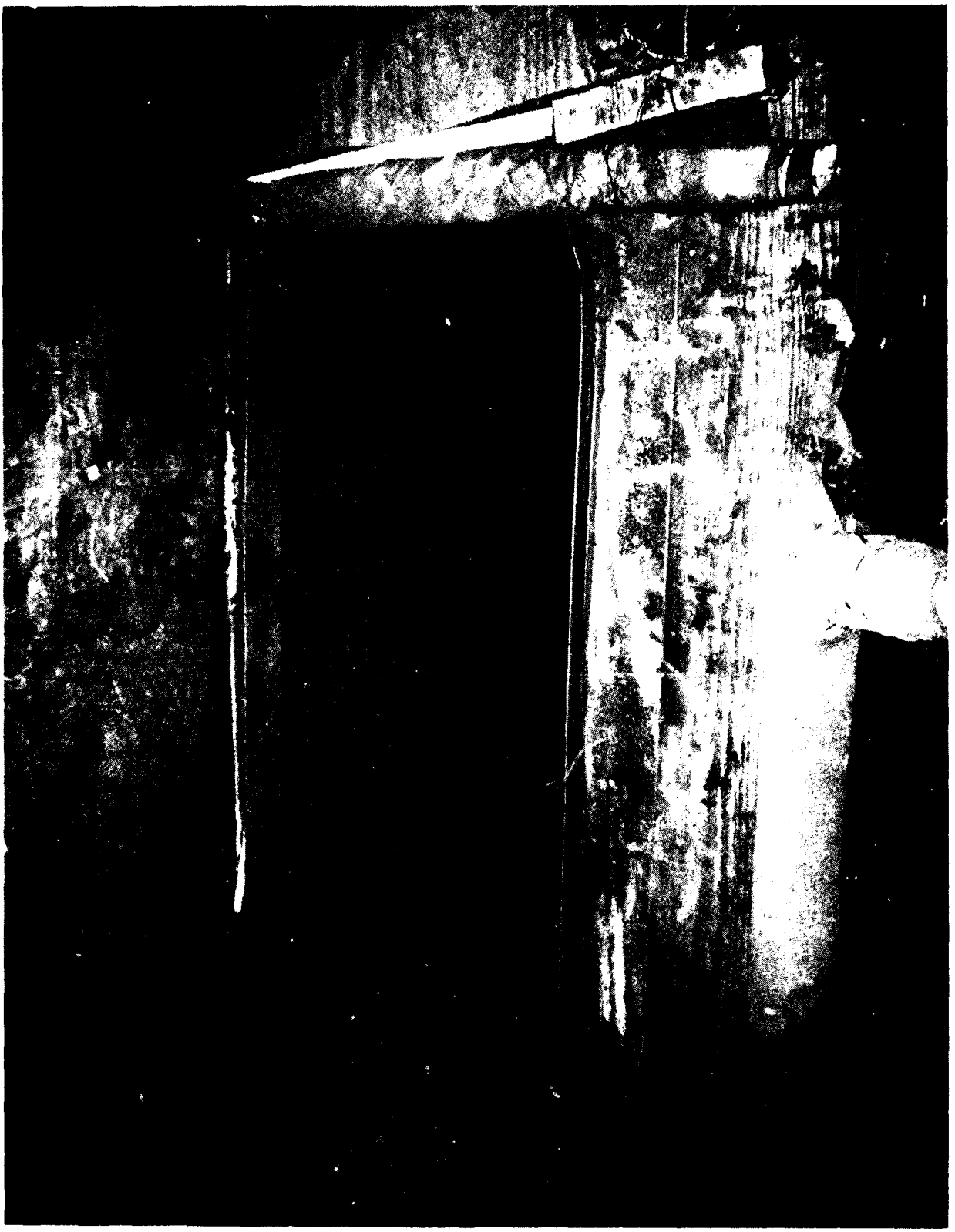


Fig. D-24 02 level starboard side. Smoke curtain hung in place in D-23.

Fig. D-25 02 level starboard side - smoke curtain in D-24 deployed.

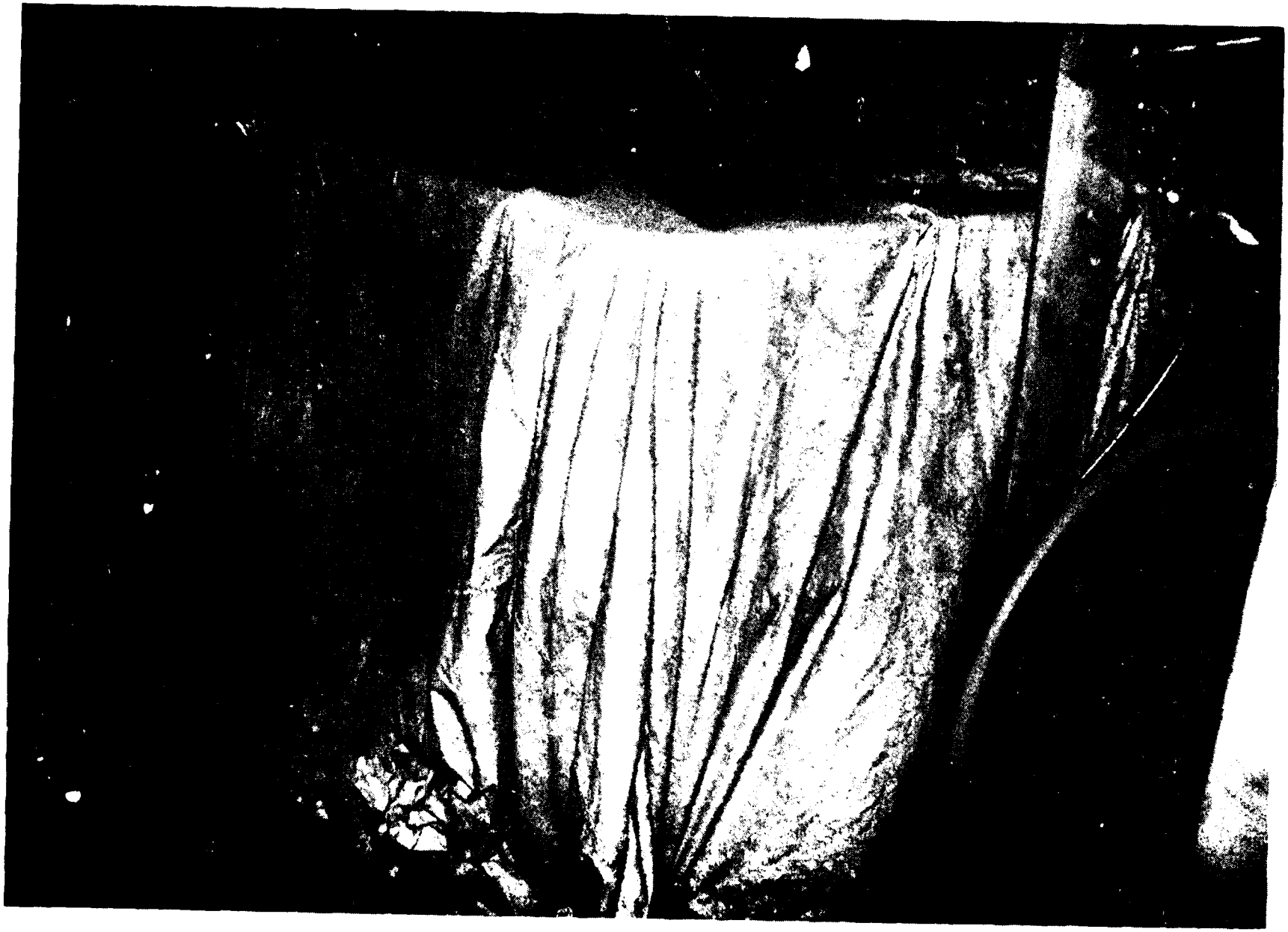


Fig. D-26 02 level thwart ships passage - smoke curtain (blanket) in place over inclined ladder going to 01 level.

Fig. D-27 02 level port side - smoke curtain permanently deployed. This is the fire/smoke side of the curtain. It is of overlap multi-strip design.

Fig. D-28 02 level port side - This is the non-smoke/fire side of the curtain shown in D-27 before a fire.

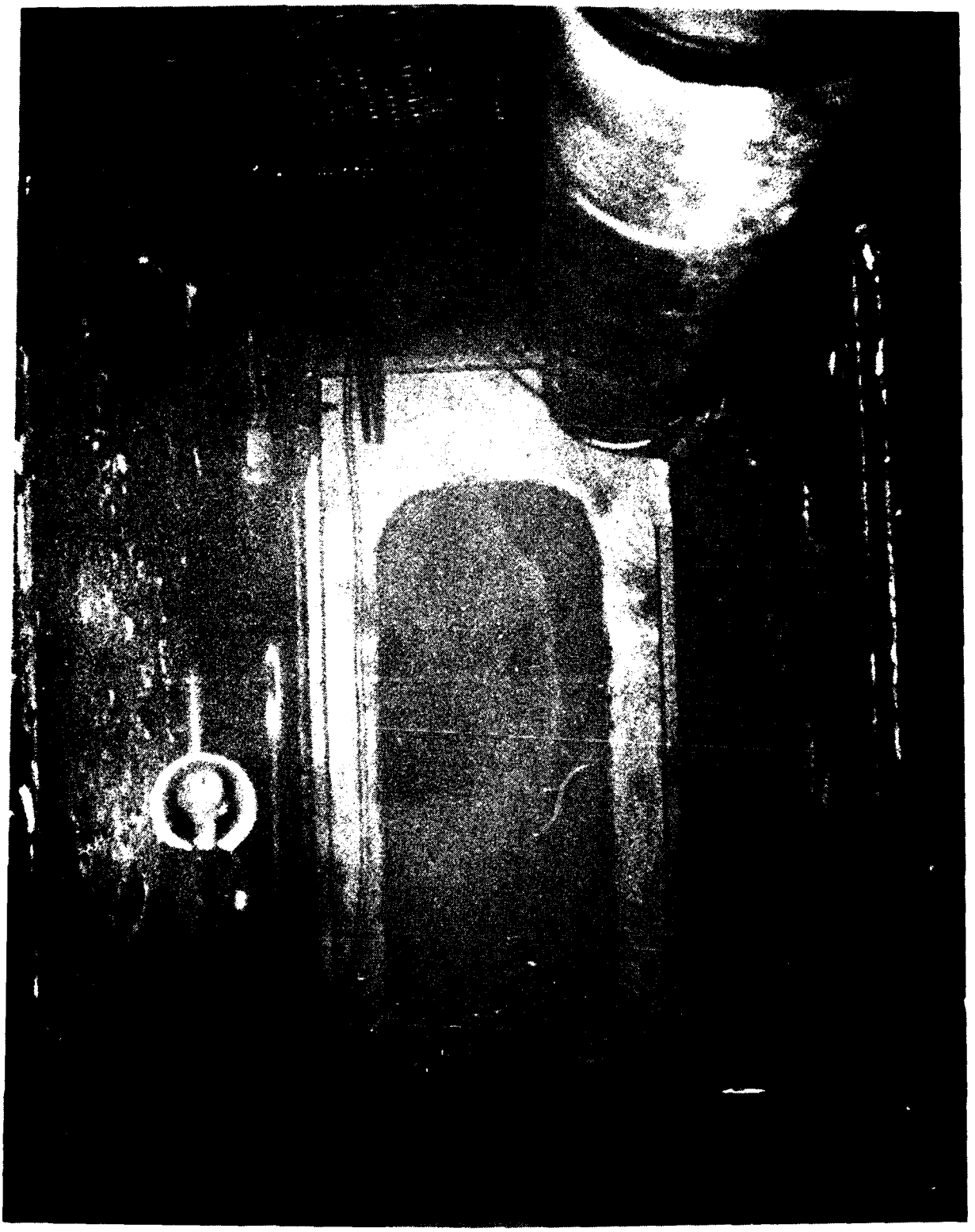


Fig. D-29 02 level port side - This is the non-smoke/fire side of the curtain shown in D-27 during a fire. Note the smoke penetrating the opening.

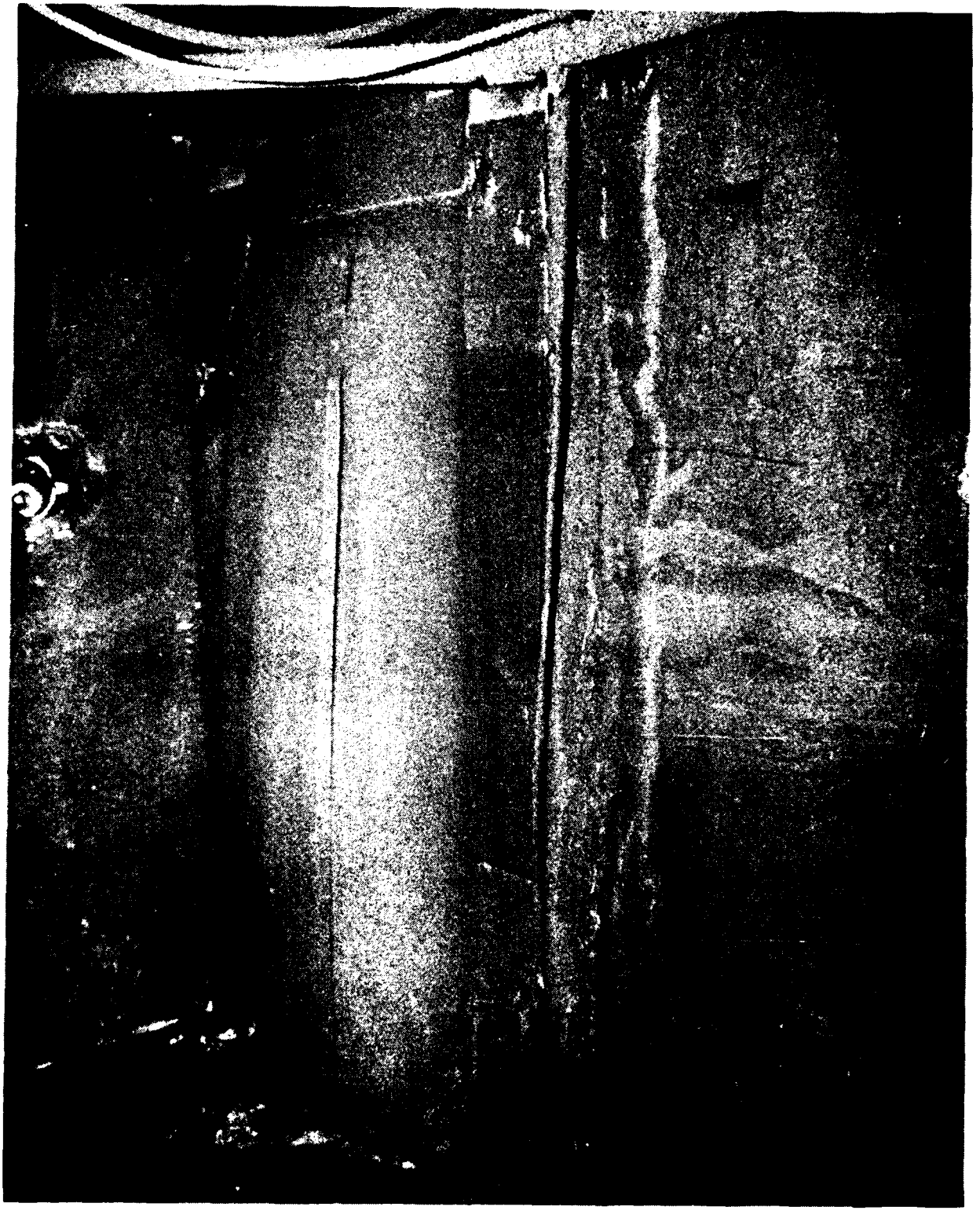


Fig. D-30 02 level port side - This is a split type curtain on the same opening as D-27 through D-29. This curtain did a better job of containing the smoke.